Magnetospheric Multiscale (MMS) Project

Solar Array Panels Specification

Effective Date: xx/xx/xx

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland

CM FOREWORD

This document is a Magnetospheric Multiscale (MMS) Project Configuration Management (CM)-controlled document. Changes to this document require prior approval of the applicable Configuration Control Board (CCB) Chairperson or designee. Proposed changes **shall** be submitted to the MMS CM Office (CMO), along with supportive material justifying the proposed change.

In this document, a requirement is identified by "**shall**," a good practice by "should," permission by "may" or "can," expectation by "will," and descriptive material by "is."

Questions or comments concerning this document should be addressed to:

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CHANGE HISTORY LOG

Revision Level	DESCRIPTION OF CHANGE	CCR / SCoRe No.	DATE APPROVED

List of TBDs/TBRs

Item No.	Location	Summary	Ind./Org.	Due Date
1				
2				

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1.0 INTRODUCTION

1.1 GENERAL INFORMATION

The Magnetospheric Multiscale (MMS) mission is the fourth mission of the Solar Terrestrial Probe (STP) program of the National Aeronautics and Space Administration (NASA). The MMS mission will use four identically instrumented observatories to perform the first definitive study of magnetic reconnection in space and will test critical hypotheses about reconnection. Magnetic reconnection is the primary process by which energy is transferred from the solar wind to the Earth's magnetosphere and is also fundamental to the explosive release of energy during substorms and solar flares.

The MMS mission will study magnetic reconnection in the Earth's magnetosphere. The four MMS observatories will be required to fly in a tetrahedral formation in order to unambiguously determine the orientation of the magnetic reconnection layer.

A sketch of the MMS spacecraft is presented in Figure 1-1.

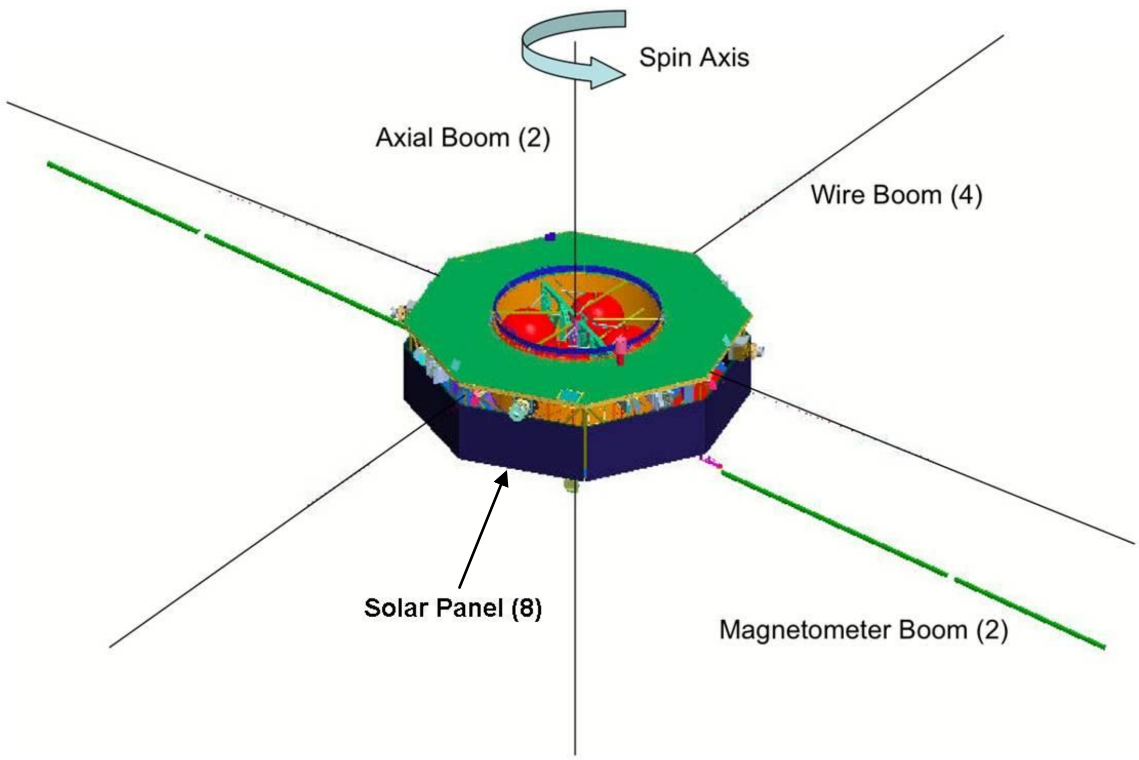


Figure 1-1. MMS Spacecraft.

1.2 SCOPE

This specification describes the electrical, mechanical, environmental, and verification testing requirements for space-qualified *Solar Array Panels* that will provide electric power for a Goddard Space Flight Center (GSFC) payload, the Magnetospheric Multiscale (MMS) Mission.

2.0 APPLICABLE DOCUMENTS

The following documents and drawings in effect on the day this specification was signed **shall** apply to the fabrication and to the electrical, mechanical, and environmental requirements of the *Solar Array Panels* to the extent specified herein. In the event of conflict between this specification and any referenced document, this specification will govern, with the exception of the Magnetospheric Multiscale *Solar Array Panels* Statement of Work (461-EPS-SOW-0010), in which case the Statement of Work (SOW) takes precedence.

The following is a list of the applicable specifications and publications.

Table 2-1 Applicable Documents

Section	Document Number	Title	Revision/Date
Many	461-EPS-SOW-0010	MMS *Solar Array Panels* Statement of Work	*TBD*
Many	461-EPS-LIST-0020	MMS *Solar Array Panels* DILS	*TBD*
Many	AIAA S-111-2005	Qualification and Quality Requirements for Space Solar Cells	Base/September 26, 2005 Notwithstanding the above, the Most Recent Revision to this Standard is Acceptable for Use Even after Contract Execution
Error! Reference source not found.	AIAA S-112-2005	Qualification and Quality Requirements for Space Solar Panels	Base/September 26, 2005 Notwithstanding the above, the Most Recent Revision to this Standard is Acceptable for Use Even after Contract Execution
Error! Reference source not found.	NASA-STD-5001A	Structural Design And Test Factors Of Safety For Spaceflight Hardware	08/05/2008
Many	ANSI/ASQC-9001-2000	Quality Management Systems - Requirements	Base/ August 1991
6.3.2	NASA-HDBK-7005	Dynamic Environment Criteria	BASE/ 3/13/2001
6.3.2	NASA-STD-7001	Payload Vibroacoustic Test Criteria	BASE/ 6/21/1996
7.1.1.2	IEST-STD-CC1246D	Product Cleanliness Levels And Contamination Control Program	2002
7.1.2.2.1	ASTM E-595-07	Standard Test Method for Total Mass Loss and Collected Volatile Condensable Materials from Outgassing in a Vacuum Environment	12/01/2007
8.1.2	MIL-DTL-5541	Chemical Conversion Coatings on Aluminum and Aluminum Alloys	07/11/2006

8.1.2	AMS 2488	Anodic Treatment - Titanium and Titanium Alloys Solution Ph 13 Or Higher	06/01/2000
Many	ASTM-E-1216	Standard Practice for Sampling for Particulate Contamination by Tape Lift	Rev -/ April 1, 2006
Many	ASTM-E-1560	Standard Test Method for Gravimetric Determination of Nonvolatile Residue from Cleanroom Wipers	Rev -/ November 1, 2006
8.1.2	MIL-A-8625F(1)	Anodic Coatings for Aluminum and Aluminum Alloys	09/15/2003
8.2.2.3.3 8.2.2.3.2 8.2.2.4.1 8.2.2.4.3	EEE-INST-002	Instructions for EEE Parts Selection, Screening, Qualification, and Derating	04/2008
Error! Reference source not found.	DOD-HDBK-83575	General Handbook for Space Vehicle Wiring Harness Design and Testing	06/04/1998
8.2.2.7	NASA-STD-8739.3	Requirements for Soldered Electrical Connections	12/15/97
Many	SAE AS 22759/33	Wire, Electrical, Fluoropolymer-Insulated, Crosslinked Modified Etfe, Lightweight, Silver-Coated, High-Strength Copper Alloy, 200°C, 600 Volt	04/01/2000
8.2.2.7	NASA-STD-8739.4	Requirements for Crimping Inter-connecting Cables, Harnesses, and Wiring	02/09/98
Error! Reference source not found.	MIL-STD-461C	Military Standard, Electromagnetic Emission And Susceptibility Requirements For The Control Of Electromagnetic Interference (Emi)	08/04/1986
Many	GSFC-STD-7000	General Environmental Verification Standards (GEVS)	April 2005

3.0 CONTRACT DESCRIPTION

3.1 *SOLAR ARRAY PANELS* DESCRIPTION

Except for the spares, each flight solar array panel is one-eighth of a body-mounted solar array for one of four MMS spacecraft. Each MMS solar array will convert solar energy to electrical power for the spacecraft In addition, in order to enable the science mission, each solar array shall be magnetically clean and electrostatically clean according to the requirements of this specification.

The contractor shall deliver flight panels, spare flight panels, a prototype panel, one or more qualification panels, and associated spare parts according to the contract schedule.

3.2 GROUND SUPPORT EQUIPMENT DESCRIPTION

GSFC will provide a hot box for the purpose of electrically testing the qualification, prototype, and flight solar array panels at their maximum predicted temperature.

4.0 FUNCTIONAL/PERFORMANCE REQUIREMENTS

The component **shall** be designed to withstand the operational and non-operational environments specified in the following section without degradation to mission goals and performance requirements.

4.1 *SOLAR ARRAY PANELS* FUNCTIONAL/PERFORMANCE REQUIREMENTS

4.1.1 Units

The contractor **shall** use metric units in all documents used for the fabrication of the MMS solar array panels. Co-use of English units on drawings is allowed.

4.1.2 Test Condition Power

4.1.2.1 Flight and Prototype Panels

Under simulated Air Mass Zero (AM0) illumination at 28 degrees Celsius (º C), normal incidence, the sum of all the solar cell string power output from strings 1 though 9 on the prototype panel and each flight panel, taken at the test connectors, shall exceed 249 watts (W) at a load voltage of 41 volts (V).

4.1.2.2 Qualification Panel(s)

The qualification panel(s) shall have at least one example of the type of circuit on the flight panels.

The qualification panel output from each of these circuits shall be at least one ninth of the panel power requirement of Section 4.1.2.1, Flight Panels.

4.1.3 Power at Highest Predicted Operating Temperature

The contractor shall extrapolate the current-voltage curves of the flight, prototype, and qualification panels to AM0 (perihelion and maximum albedo), 40ºC.

4.1.4 Power at Highest Predicted Temperature

The contractor shall extrapolate the current-voltage curves of the flight, prototype, and qualification panels to 1.405 AM0 (perihelion and maximum albedo), 60ºC. The current at 28 V of any string (18 solar cells in series), taken at the test connector, shall never exceed 0.98 amperes at 1.405 AM0, beginning of life (BOL), at 60ºC.

4.1.5 End-of-Life Power

The contractor shall predict the panel I-V curve, taken at the test connector and at the flight connector, for the MMS flight panels under 0.967 AM0 illumination at -160°C, -60°C, 40ºC, 60ºC, and 70ºC after exposure to the space environment for an interval of 28 months, which is the contractually defined end of life (EOL) for the array. The prediction shall be presented with both graphical and tabular data and shall include the values of short-circuit current (Isc), open-circuit voltage (Voc), current at maximum power (Imp), voltage at maximum power (Vmp), maximum power (Pmax), and power at 35V. The prediction shall account for all environments defined in this specification including the effects of thermal cycling. The prediction shall also account for off-pointing of the panels from the sun line by 5º about the long axis of the panels.

4.1.6 Radiation Hardness

The contractor shall select all parts to meet their intended application after exposure to the on-orbit MMS radiation environment described in Section 10.5 of this specification.

For the solar cells, the Contractor shall use Spenvis to determine the 1-MeV electron equivalent fluence at end of life.

4.1.7 Bypass Diode Functionality

The bypass diode circuits shall be functional subsequent to panel fabrication and through the end of environmental testing and for the flight panels, through end of life.

4.1.8 Bypass Diode Functionality at High Temperature

The bypass diode circuits shall be functional at high temperatures subsequent to array fabrication and through the end of environmental testing and for the flight panels, through flight.

4.1.9 Radius of Curvature

The solar panels shall withstand a radius of curvature of 1016 centimeters (cm) or more without damage.

4.1.10 Solar Cell and Bypass Diode

4.1.10.1 Solar Cell Mechanical

No cell on a panel shall have a crack, visible at 7x or less magnification.

4.1.10.2 Solar Cell Layout

The solar cell layout for each panel **shall** consist of 9 strings of 18 solar cells in series. The series direction is depicted in Figure 8-1. The contractor **shall** use the largest solar cell dimensions that feasibly fit on the panel in both the series and parallel directions while also meeting the electrostatic cleanliness requirements of Section 7.2. There are no stay-out zones on the front side of the panel.

4.1.10.3 Solar Cell Power

At 28°C and Air Mass Zero, the MMS solar cell shall produce more than 39.6 mw/cm^2 using the solar cell's total area.

4.1.10.4 Limit to Solar Cell Shadowing

No cell shall experience more than 3 percent degradation in maximum power output as a result of the panel being repeatedly partially shadowed.

4.1.11 Solar Cell Cover

4.1.11.1 Cover Orientation

The contractor shall orient the cover using either an etch symbol or a stain.

4.1.11.2 Indium Tin Oxide Coating

The contractor shall use covers that are coated with Indium Tin Oxide having a resistivity of less than 5000 ohms per square and connect each cover to ground. The covers shall not have an anti-reflection (AR) coating.

4.1.12 Blocking Diodes and Terminal Boards

4.1.13 Platinum Resistor Thermometer (PRT)

4.1.13.1 PRT Type

The contractor shall use Goodrich Platinum Resistor Thermometer type 118MF2000AEAAAC.

4.1.13.2 PRT Mounting

The contractor shall locate the PRT on the back side of the front face sheet in a cavity it machines into each panel.

The contractor shall locate the PRT under the geometric center of a row or column of cells very roughly in the geometric center of the panel.

The contractor shall run the lead wires from the PRT on the back side of each panel to the connector.

4.1.13.3 PRT Performance

The PRT shall meet its manufacturer's specifications for resistance versus temperature.

4.1.14 Insulated Substrate

The contractor shall supply insulated substrates for the qualification, prototype, and flight panels.

The contractor shall equip the prototype and flight substrates with fittings suitable for attaching handles and handling fixtures per TBD(needed from Mechanical).

4.1.14.1 Substrate Insulation Resistance

The resistance between the substrate and the solar cell circuits shall be greater than 1000 megohms per square meter of cell area for the flight panels, prototype panel, and qualification panel(s).

4.1.14.2 Substrate Grounding

The contractor shall run two AWG #20 ground wires from each substrate to ground contacts on the panel connectors.

The resistance to ground shall be less than 2 ohms.

4.1.15 Panel Performance in Vibration and Acoustic Noise Environment

The flight, qualification, and prototype panels shall meet the requirements of this specification after exposure to the vibration and acoustic noise resulting from launch. see Table 6-6, Limit Level Acoustic Environments

The contractor shall not perform an acoustic test on the qualification panel(s).

4.1.16 Panel Performance in Thermal Vacuum Environment

No flight panel shall degrade in peak power by more than 2 percent and no panel shall incur damage that may question its reliability to meet the requirements of this document after exposure to the flight thermal cycles in the vacuum of space as specified in Table 6-2.

4.1.17 Panel Performance in Depressurization Environment

The flight, prototype, and qualification solar array panels shall meet the requirements of this document after depressurization from 1 atmosphere to 1E-05 Torr in thirty seconds.

4.1.18 Allowable Degradation Due to Charged Particle Radiation

The contractor shall consider hard particle radiation in its computation of end of life power, see section 4.1.5.

4.1.19 Allowable Degradation Due to Humidity

The qualification, prototype, and flight solar panels shall meet the requirements of this document during and after exposure of 20 to 70% relative humidity after (2) years.

4.2 RESOURCE ALLOCATIONS

N/A
N/A
N/A
N/A

4.3 POWER

N/A
N/A
N/A
N/A
N/A
N/A
N/A
N/A

4.3.1.1 Primary Power Return Ground

Solar Array Panels **shall** provide Primary Power return in the same connector as the primary power. The power output wires should be kept as close as possible to their return wires to obtain the best possible magnetic field self-cancellation on the panels, as well as through the connectors (i.e. adjacent pins). See the Magnetics Cleanliness section for more information.

4.3.1.2 Solar Array Panels Power Wire Redundancy

The *Solar Array Panels* **shall** provide redundant contacts or connections for the outputpower and return lines.
N/A

4.3.2 N/A

N/A
N/A
N/A
N/A
N/A
N/A

4.4 ELECTRICAL GROUNDING

4.4.1 Power DC Isolation

4.4.1.1 Power DC Isolation from Signal Ground

The *Solar Array Panels* power and power returns **shall** be isolated from signal grounds by a DC resistance of greater than or equal to 10 MΩ.

4.4.1.2 Primary Power DC Isolation from Component Chassis

At the *Solar Array Panels* primary power and primary power returns **shall** be isolated from the component chassis by a DC resistance of greater than or equal to 10 MΩ.

4.4.2 N/AN/AN/AMechanical Contact Impedance

The DC resistance of the mechanical contact between two conductive mating surfaces (internal to the component, and at the spacecraft interface) **shall** be less than or equal to 2.5 mΩ DC resistance.

4.4.3 Mating Method

The primary mating method for a component **shall** be metal-to-metal contact between component mounting feet (or base plate) and the spacecraft structure.TBD(Needed from Mechanical-substrate has composite facesheets-Al inserts for mounting holes?)
N/AN/A
N/A
N/A

4.5 SIGNAL AND DATA INTERFACES

All of the requirements in this section need to be worked with the Electrical Systems lead. Many of these will not apply to your procurement. If the procured item is a COTS unit, be sure to not levy requirements that will drive up cost!!
N/A
N/A
N/A
N/A
N/A
N/A
N/A
N/A
N/A
N/A

5.0 PHYSICAL REQUIREMENTS

5.1 INTERFACE DOCUMENTATION

The mounting interface **shall** be defined in the Mechanical Interface Control Drawing (ICD), which will be developed between the contractor and NASA GSFC. Should be provided by GSFC to contractor in the RFP, either as part of this spec or as an ICD-TBD.

The electrical interface is defined in this Specification.

N/A

5.2 MASS PROPERTIES

5.2.1 Component Masses

The add-on mass (total assembled panel mass minus the substrate mass) of Each Solar Array Panel **shall** be less than *2.4* kg. The mass of each Solar Array Panel substrate shall be less than 2.7 kg.

5.2.2 Center of Mass Location

The contractor **shall** define the center of mass.

5.2.3 Center of Mass Accuracy

The contractor shall determine the center of mass to within *±2.5 mm* relative to an external reference.

5.2.4 Determination of Moments and Products of Inertia

The contractor shall calculate the final moments and products of inertia of the*Solar Array Panel*.

5.3 PHYSICAL ENVELOPE

No *Solar Array Panel* **shall** exceed the thermal and mechanical volume envelope in Figure 5-1(TBD-Needed from mechanical for new dimensions).

The front-side dimensions of the panel are presented in Figure 5-1.

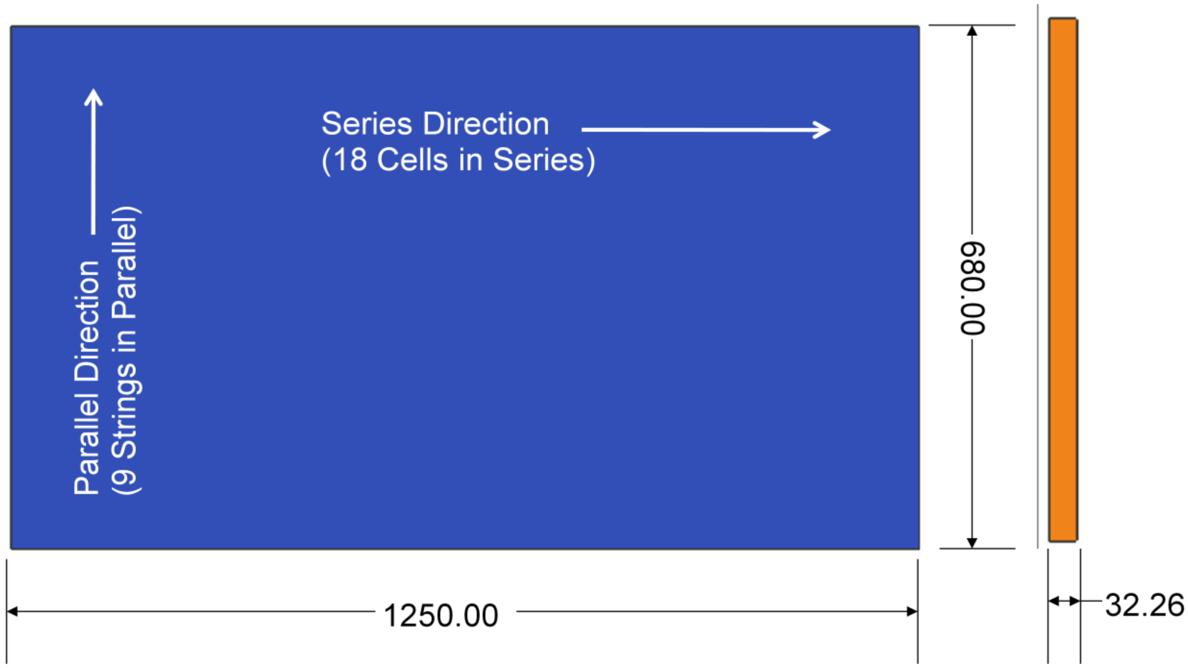


Figure 5-1. Front and Side Dimensions of Insulated Substrate (Units are mm).

The back side dimensions of the solar array panel are presented in Figures 5-2a and b.

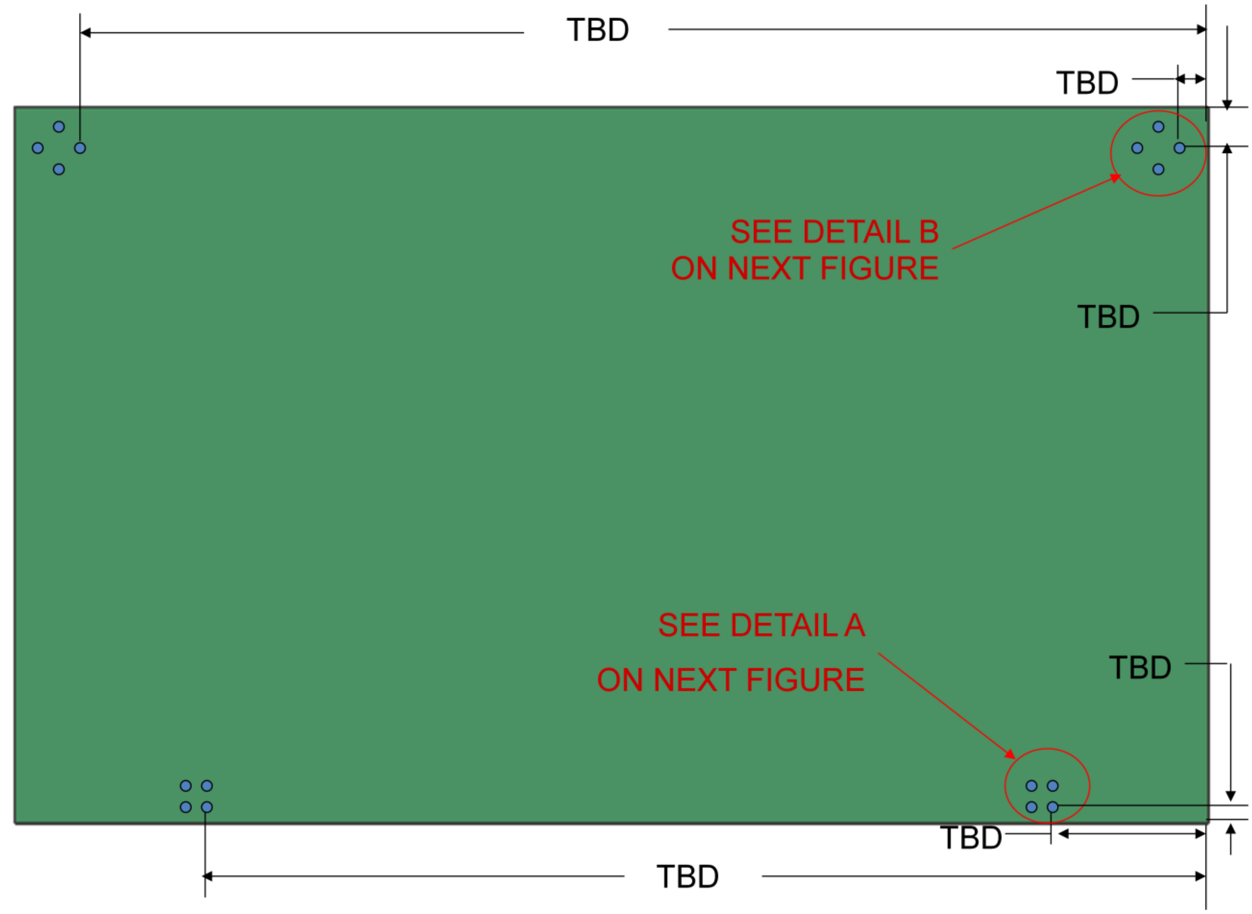


Figure 5-2a. Solar Array Panel Back Side Dimensions (mm)

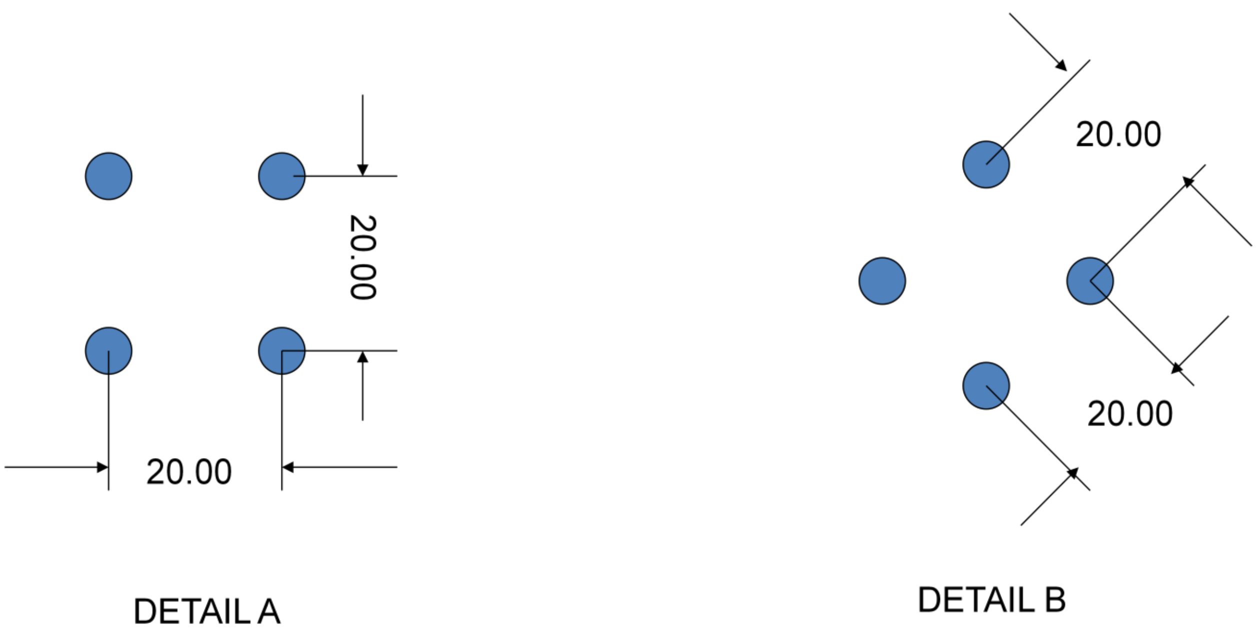


Figure 5-2b. Hole Pattern Details from Figure 5-2a.

5.4 MOUNTING

Include here any requirements for surface flatness, hole locations, mounting hardware, thread locking features etc. TBD-drawing showing mounting holes, edge attachment points, etc. needed from mechanical.
N/A
N/A

6.0 ENVIRONMENTAL REQUIREMENTS

Environmental design requirements for the spacecraft components are specified in this section. The MMS spacecraft components will be capable of meeting their performance requirements after exposure to the environments specified in this section.

All loads and environments in this document are preliminary and will be updated as the MMS spacecraft is defined.

6.1 COMMENT: THE SOLAR CELLS AND OTHER ELECTRICAL COMPONENTS ON THE SOLAR ARRAY ARE NOT STRUCTURAL COMPONENTS. FORCING THEM TO MEET THIS REQUIREMENT WOULD MAKE THE ARRAY INTOLERABLY HEAVY. MAY APPLY TO SUBSTRATES?QUASI-STATIC ACCELERATION

Quasi-static acceleration represents the combination of steady-state accelerations and the low frequency mechanically transmitted dynamic accelerations that occur during launch.

Each *Solar Array Panel* **shall** demonstrate its ability to meet its performance requirements after being subjected to the net CG limit loads shown in Table 6-1.

Linear interpolation should be used between breakpoints to determine the appropriate limit load as a function of *Solar Array Panel* weight. Note that these design limit loads are intended to cover only the low frequency launch environment and must be used in conjunction with the random vibration environments to assess structural margins.

Table 6-1 Solar Array Panel Limit Loads

Solar Array Panel **Mass (kg)**	**Limit Load (g, any direction)**
0.5 or less	35.9
1	35.0
5	30.1
10	26.5
20	22.4
40	18.2
60	15.9
80	14.3
100	13.2
125	12.1
150	11.2
175	10.6
200	10.0

225	9.5

6.2 FREQUENCY REQUIREMENT

6.2.1 Fundamental Launch Frequencies

The *Solar Array Panels* **shall** have a fundamental frequency greater than *50* Hz when hard mounted at its SC interface.

6.3 VIBRATION

6.3.1 Sinusoidal Vibration

Each Solar Array Panel **shall** demonstrate its ability to meet its performance requirements after being subjected to the sine vibration environment in Table 6-2, applied at the MMS to *Solar Array Panel* interface. See Section 10.4.1 for definitions of Protoflight, Qual, and Acceptance.

Table 6-2 *Solar Array Panel* Sine Vibration Environment

Frequency	Protoflight/Qual Level	Acceptance Level
5 - 50 Hz	12.5 g's (4 oct/min protoflight and 2 oct/min prototype hardware)	10 g's (4 oct/min)

Levels may be notched to not exceed 1.25 times the design limit load. These levels will be updated as coupled-loads analysis (CLA) data becomes available. *Each Solar Array Panel* **shall** test for this environment up to 50 Hz and be analyzed from 50 to 100 Hz. Peak levels at the low end of the frequency range (5 – 20 Hz typically) may be ramped up as needed to accommodate shaker table displacement limitations.

6.3.2 Random Vibration

The *Solar Array Panel* **shall** demonstrate its ability to meet its performance requirements after being subjected to the random vibration environment in Table 6-3, applied at the MMS to *Solar Array Panel* interface.

Table 6-3 *Solar Array Panel* Random Vibration Environment

Frequency (Hz)	Protoflight/Qual Level	Acceptance Level
20	0.026 g^2/Hz	0.013 g^2/Hz
20 – 50	+6 dB/Octave	+6 dB/Octave
50 – 800	0.160 g^2/Hz	0.080 g^2/Hz
800 – 2000	-6 dB/Octave	-6 dB/Octave
2000	0.026 g^2/Hz	0.013 g^2/Hz

Over All	14.1 grms	10.0 grms
Duration (minutes)	1 (protoflight), 2 (Qual)	1

Solar Array Panel, the highest design loads may be from this random vibration environment. The contractor **shall** perform random vibration analysis along with static loads analysis. Please see NASA-HDBK-7005 and NASA-STD-7001 for more information.

6.4 SHOCK

Each *Solar Array Panel* **shall** be designed to meet its performance requirements after being subjected to the shock environment in Table 6-4, applied at the *Solar Array Panel* interface.

Table 6-4 Limit Level Shock Response Spectrum

Frequency (Hz)	Level (Q=10)
100 100 to 800 800 to 3000	*TBD* g + *TBD* dB/Octave *TBD* g
3000 to 10000 10000	+ *TBD* dB/Octave *TBD* g

6.5 ACOUSTICS

Each *Solar Array Panel* **shall** be designed to meet its performance requirements after being subjected to the acoustic environment listed in Table 6-.

Table 6-1 Limit Level Acoustic Environments

Center Frequency (Hz)	Max Predicted Sound Pressure Level (dB)
25	114.0
31.5	120.3
40	127.5
50	122.5
63	124.0
80	124.5
100	126.0
125	126.0
160	127.1
200	127.0

250	126.5
315	126.0
400	126.0
500	124.5
630	122.0
800	119.5
1000	116.5
1250	114.0
1600	112.0
2000	114.0
2500	111.0
3150	110.0
4000	109.0
5000	108.5
6300	108.0
8000	109.7
10000	110.5
OASPL	137.1
Duration	1 minute flight and 2 minutes non-flight hardware

The reference point is 20 μPa.

6.6 TRANSPORTATION

All Transportation loads that the *Solar Array Panels* are exposed to **shall** be less than the Quasi-Static, Vibration, Shock, and Acoustic loads previously defined.

6.7 PRESSURE

6.7.1 Operating Pressure Range

The *Solar Array Panels* **shall** be designed to meet all performance requirements while operating over a pressure range of 1.08 x 10^5 N/m^2 (813 Torr) to 1.3 x 10^{-12} N/m^2 (1 x 10^{-14} Torr).

6.7.2 Maximum Depressurization Rate

The *Solar Array Panels* **shall** be designed to meet all performance requirements after exposure to a maximum depressurization rate of 6205.3 N/m^2/second (46.54 Torr/sec) experienced during launch and ascent.
N/A
N/A
N/A
N/A

6.8 HUMIDITY

The *Solar Array Panels* **shall** be able to meet performance requirements after exposure to relative humidity levels of 35% to 70%.

6.9 THERMAL REQUIREMENTS

6.9.1 Operational Temperature Limits

The solar array panels shall meet the requirements of this document after exposure to the temperature extremes and number of eclipse cycles in Table 6-2.

Table 6-2 Solar Array Panel Temperature Environment

Number of Cycles	Temperature Limits
807	**-60°C to +60°C**
80	**-160°C to +60°C**

6.9.2 Ground Test Environment

The *Solar Array Panels* **shall** be able to operate in a lab environment with air temperature between 15 and 25 degrees C and relative humidity between 35 and 70%.

The *Solar Array Panels* **shall** survive without degradation during transportation temperatures of +15 to +30 degrees C and relative humidity of 0 to 70%.

6.10 N/ACHARGE PARTICLE RADIATION REQUIREMENTS

The Solar Array Panels will be exposed to a natural space radiation environment that consists of: (1) trapped particles which include electrons, protons, and heavier ions; (2) particles from solar events (coronal mass ejections and flares); and (3) galactic cosmic ray particles.

For solar cell degradation, the contractor shall use SPENVIS to determine the 1-MeV electron equivalent fluences for Isc, Voc, and Pmax at EOL. The contractor shall assume infinite backshielding for the purpose of this calculation.

6.10.1 Definitions

Total Ionizing Dose (TID) - the mean energy deposited by ionizing radiation in a device region divided by the mass of the region. This is often given in units of rad(Si), where 1 rad(Si) = 100 erg deposited per gram of silicon.

Displacement Damage Dose (DDD) - the mean energy deposited by ionizing radiation in a device region that goes into atomic displacements divided by the mass of the region. There is no official unit for DDD. One such unit is MeV/g

1-MeV Electron Equivalent Fluence The fluence that, for a given environment, produces the equivalent solar cell degradation to that of the isotropic charged particle environment.

Equivalent Fluence Method A computational method of converting the isotropic charged particle environment to a normally-incident 1-MeV electron equivalent.

Relative Damage Coefficient (RDC) Experimentally-generated coefficients that relate the amount of damage from isotropic protons and electrons of various energies to that of an equivalent 1-MeV electron fluence at normal incidence.

SPENVIS Space Environment Information System. An ESA web-based model of the space radiation environment that includes a program to calculate 1-MeV electron equivalent fluences for determining solar cell degradation due to charged particle radiation.

Non-Ionizing Energy Loss (NIEL) - a measure of the rate of energy loss due to atomic displacements as a particle traverses a material.

6.10.2 Total Ionizing Dose

6.10.2.1 Minimum TID Tolerance for EEE Parts (non-bipolar/bi-CMOS)

All EEE parts on the Solar Array Panels **shall** be able to tolerate two times (x2) the dose shown for the TID curves in Figure 6-1, using only the shielding afforded by the panel design.

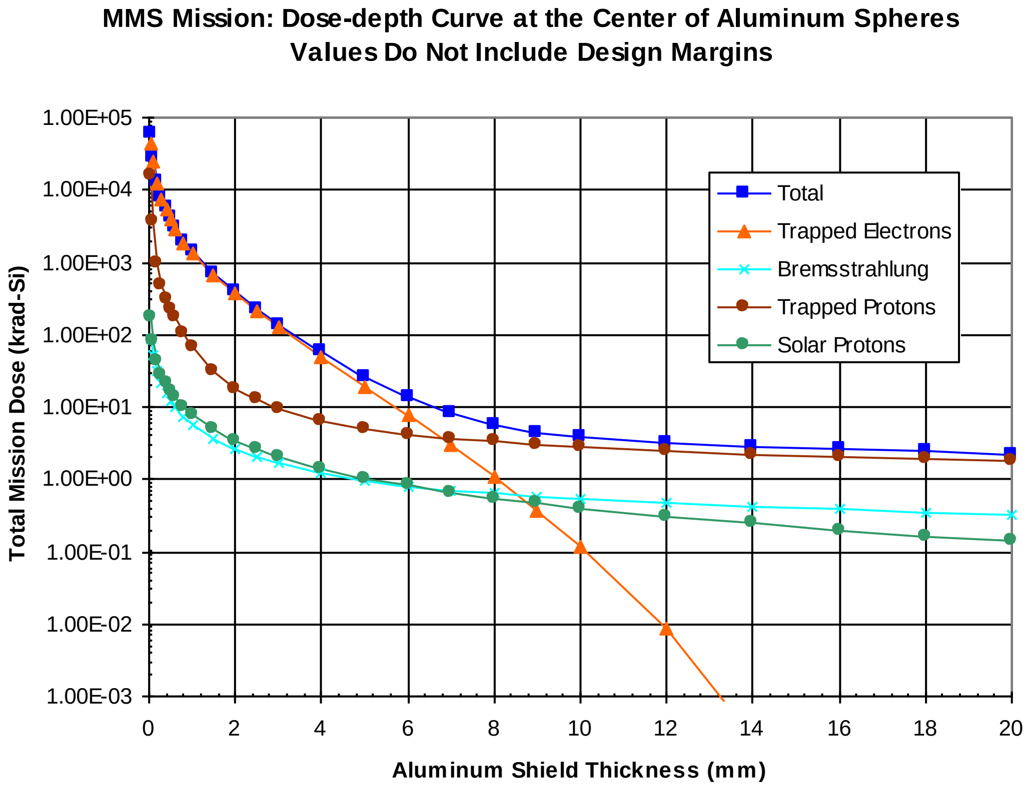


Figure 6-1 Total Dose for MMS Orbits

N/A

6.10.3 Displacement Damage Dose

All DDD susceptible EEE parts shall not sustain permanent damage or performance degradation due to a minimum 10 MeV equivalent proton fluence of 3.4×10^{11} cm^{-2}.
N/A

6.10.4 Trapped Protons

The trapped proton integral fluence spectrum that the contractor shall use in calculating the 1-MeV electron equivalent fluence is specified in Table 6-3.

Table 6-3 Spacecraft Incident Integral Trapped Proton Fluence for MMS Mission

Values Do Not Include Design Margins

E, ENERGY (MeV)	AVERAGE INTEGRAL FLUENCE ABOVE E

	(p/cm^2)
0.1	8.88E+14
0.3	3.49E+14
0.5	1.67E+14
1	4.04E+13
1.5	1.38E+13
2	5.62E+12
3	2.20E+12
4	1.06E+12
5	6.62E+11
6	4.34E+11
7	3.12E+11
10	1.40E+11
15	5.95E+10
30	2.49E+10
50	1.71E+10
100	9.25E+09
200	3.01E+09
300	1.10E+09
400	4.08E+08

6.10.5 Trapped Electrons

The trapped electron integral fluence spectrum that the contractor shall use in calculating the 1-MeV electron equivalent fluence is specified in Table 6-4.

Table 6-4 Spacecraft Incident Integral Trapped Electron Fluence for MMS Mission

Values Do Not Include Design Margins

E, ENERGY (MeV)	AVERAGE INTEGRAL FLUENCE ABOVE E (e/cm^2)
0.04	1.08E+15
0.1	5.97E+14
0.2	3.01E+14
0.3	1.75E+14
0.4	1.11E+14
0.5	7.22E+13

0.6	5.25E+13
0.7	3.86E+13
0.8	2.96E+13
1	1.87E+13
1.25	1.10E+13
1.5	6.55E+12
1.75	4.12E+12
2	2.60E+12
2.5	1.05E+12
3	4.19E+11
4	5.90E+10
5.5	1.01E+9
7	4.16E+06

6.10.6 Solar Protons

The solar proton integral fluence spectrum that the contractor shall use in calculating the 1-MeV electron equivalent fluence is specified in Table 6-5.

Table 6-4 Spacecraft Incident Solar Proton Fluence for MMS Mission

Values Do Not Include Design Margins

Energy (>MeV)	**Fluence (p/cm^2)**
0.5	2.20E+11
1	1.80E+11
2	1.20E+11
3	7.80E+10
4	5.70E+10
5	4.50E+10
6	3.70E+10
8	2.70E+10
10	2.00E+10
15	1.20E+10
20	7.70E+09
25	5.30E+09
30	3.90E+09
35	3.00E+09

40	2.30E+09
45	1.90E+09
50	1.50E+09
60	1.10E+09
70	7.70E+08
80	5.80E+08
90	4.40E+08
100	3.50E+08
120	2.30E+08
140	1.60E+08
160	1.10E+08
180	8.20E+07
200	6.30E+07

7.0 CLEANLINESS

At delivery, each *Solar Array Panel* should be sufficiently clean so as not to adversely affect its own performance, as well as not be a source of contamination to other items. In addition, the *Solar Array Panels* should not generate contaminants following delivery in excess of that permitted below by virtue of its design, materials of construction, or operation.

7.1 SURFACE CONTAMINATION

7.1.1 Surface Contamination Levels At Delivery

7.1.1.1 Particulate Contamination

The *Solar Array Panels* **shall** be free of particulate and molecular contamination when inspected with a bright and white light in a darkened room.

7.1.1.2 Molecular Contamination

The *Solar Array Panels* **shall** meet a molecular surface cleanliness level of A/3 per IEST-STD-1246D on all external and critical surfaces, when tested in accordance with IEST-STD-1246D.

7.1.2 Surface Contamination Generation

7.1.2.1 Particulate Generation

The *Solar Array Panels* contractor **shall** not employ any of the following particle generating materials or processes into the *Solar Array Panels* design or construction without prior approval from NASA/GSFC:

- Paints prone to shedding due to large paint pigment molecules, overspray, poor adhesion, etc.
- Dry lubricants (e.g. molybdenum disulfide).
- Surfaces prone to corrosion or oxides because of a lack of corrosion protection or dissimilar metals in close contact.
- Fabrics with brittle constituents (e.g., composites, graphite or glass).
- Perforated materials when material is highly susceptible to tear propagation (e.g., MLI).
- Metal oxides (bare [untreated] aluminum and magnesium, iron, non- corrosion resistant steel, etc.).
- Braided metallic or synthetic wires, ropes, slings, etc. unless measures have been taken to contain any broken filaments or fibers (sheathing, sealing with polymers, covering, etc.).

- Woven materials especially cut or unfinished ends (metal braid, EMI shielding, lacing cord, expando sleeving), unless measures have been taken to prevent fraying or generation of particles (cut with a hot knife, seal with polymer, bag, etc).
- Materials with thin films known to erode or crack or flake when subjected to normal handling (e.g., indium tin oxide [ITO] or other rigid or brittle semiconductor or ceramic coating on flexible substrates, Teflon, multi-layered insulation [MLI], etc.).
- Foams, highly textured materials.
- Trapped debris in holes.

7.1.2.2 Molecular Generation

7.1.2.2.1 Material Selection

The *Solar Array Panels* materials **shall** have a total mass loss (TML) less than 1.00% and a collected volatile condensable mass (CVCM) less than 0.10%, as specified in ASTM E-595 unless a materials usage agreement has been generated and approved by NASA/GSFC.

7.1.2.2.2 Assembly Outgassing

When measured in a vacuum of 10E-6 torr at 50 °C, the *Solar Array Panels* outgassing **shall** not exceed 2E-10 g/sec per kg of unit under test of mass that is condensable on a Quartz Crystal Monitor (QCM) that is operated at -20 degrees.

7.1.3 Wiping and Cleaning Materials

The contractor shall only use extracted wipes to clean the solar panels, solar cells and covers.

All wipes or other items used to clean the panels shall be Soxhlet extracted for a minimum of 24 hours and dried before use. (Commercial product is available that meets this requirement.)

All materials used including solvents, cleansers, gloves, finger cots etc. shall be compatible with the primers and adhesives used in solar panel fabrication.

No material shall introduce contamination that might affect proper adhesion of one part to another.

7.1.4 Gloves and Finger Cots

The contractor shall only use latex free, powder free, polyethylene gloves and finger cots to touch completed CICs and panels in the presence of solvents.

The contractor shall only use powder free latex or nitrile gloves or finger cots on dry CICs and panels.

7.1.5 Room Cleanliness

The contractor shall manufacture and test hardware in an ISO Class 8 facility per ISO-14644.

7.1.6 Assembly Room Temperature

The contractor shall assemble the solar panels in a room between 18C and 28C.

7.1.7 Assembly Room Humidity

The contractor shall assemble the solar panels in a room having a humidity range proposed by the contractor.

7.2 ELECTROSTATIC CLEANLINESS

The following paragraphs provide requirements and guidelines for minimizing the magnitude and variations in the radiated electric field from the external surfaces of the *Solar Array Panelsd* when exposed to the space plasma. All external Observatory surfaces which are exposed to the space plasma should be sufficiently conductive and be connected to spacecraft ground through low impedance paths such that the potential difference between any point on the surface and the spacecraft ground is less than 0.5V when exposed to an 8nA/cm^2 plasma flux. Exposed insulating materials are not desirable, but may be acceptable if they meet the requirements below. Likewise apertures that may expose internal insulating or non-grounded conducting surfaces to the space plasma are not desirable, but may be acceptable if they meet the requirements below.

7.2.1 Approved Exposed Materials

All external *Solar Array Panels* surfaces **shall** be made from one of the following conductive materials.

Table 7-1 Exposed Materials

Material	Max Value (Ohms/sq)	Max Area/Ground (cm^2) dVmax/(Jmax*(Rg+Rsurf))
MIL-DTL-5541 Class 3	1	10416667
Aluminum	1	10416667
Black Kapton 160XC	450	137363
Copper	1	10416667
Copper & Gold	1	10416667

DAG213	11000	5679
GeBK (blankets or tape)	13000	4806
Gold	7	5208333
Graphite fibers	90	657895
Graphite with epoxy, abraded	3500	17832
ITO	5000	12488
Magnesium	1	10416667
Electroless Nickel	10	4166667
Nickel Plated Fiberglass	10	4166667
Silver Plated	10	4166667
Stainless Steel	10	4166667
Titanium	10	4166667
VDA	9	4464286
Z307	100000	625

The max value surface resistivity and max areas are for reference only, based on previously measured surface resistivity values, and a calculated area using the assumption that the resistance between a single surface ground point and the spacecraft single point ground is 5 ohms.

7.2.2 Exposed Conductive Surfaces

Conductivity of surfaces (such as metal panels, tape, thermal blankets) that can bleed charge across their surface and out through one or more edge ground strips or ground wire points, is often specified in terms of surface resistivity. Materials that are applied as thin coatings on other conductive surfaces are often specified in terms of bulk resistivity. Materials such as paints that are not homogeneous, while having bulk or surface resistivity measured values, may not behave as simple resistors as assumed in the below requirements, and should be assessed based on their ability to meet the conductive surface to ground voltage requirement.

7.2.2.1 Conductive Surface Ground Path

All *Solar Array Panels* external conductive surfaces **shall** be connected to the spacecraft interface with a resistance less than 5 ohms, either through the use of ground wire(s) or through metal-to-metal mounting contact.

7.2.2.2 Conductive Surface Resistivity

7.2.2.2.1 Conductive Surface Resistivity Magnitude

All exposed solid conductive surfaces **shall** have a surface resistivity of less than 62.5 x (N/A) - R_{ground} Megohms per square where A is the exposed area in square centimeters and N is the number of connections to the next grounded material, and R_{ground} is the resistance between the surface ground points and the spacecraft interface.

7.2.2.2.2 Conductive Surface Resistivity Grounding

All exposed solid conductive surfaces **shall** have a minimum of two (2) connections to the mounting interface with the Spacecraft.

7.2.2.2.3 Conductive Surface Resistivity of Coatings on Dielectric Surface with Point Grounds

Coatings applied over a dielectric surface **shall** have a surface resistivity of less than 62.5 x (N/A) – R_{ground} Megohms per square, where A is the exposed area in square centimeters, N is the number of ground connections to the next grounded material, and R_{ground} is the resistance between the surface ground points and the spacecraft interface.

7.2.2.3 Conductive Bulk Resistivity

7.2.2.3.1 Conductive Bulk Resistivity of Coatings on Conductive Surface

Exposed coatings or paints deposited over conductive surfaces **shall** have a bulk resistivity of less than (62.5-R_{ground}*A)/T Megohm-cm where R_{ground} is the resistance between the surface ground points and the spacecraft interface, A is the exposed area in square centimeters, and T is the thickness of the coating in centimeters.

7.2.2.3.2 Conductive Coatings on Dielectric Surface, Grounding

Exposed coatings applied over a dielectric surface **shall** have a minimum of two (2) connections to the spacecraft interface.

7.2.2.4 Solar Panels

The solar array will be designed to the following requirements:

7.2.2.4.1 Conductivity

All cover glasses **shall** be conductively coated to meet the surface resistivity requirements.

7.2.2.4.2 Open Areas

Areas between cells and all perimeter areas **shall** be covered by conductive layers.

7.2.2.4.3 Interconnects

All cell interconnects **shall** be covered by conductive shielding.

7.2.2.4.4 Insulators

No exposed insulators **shall** be present.

7.2.2.4.5 Grounding

All surfaces **shall** be connected with at least two ground paths to the spacecraft interface.
N/A

7.2.2.5 Exposed Conductive Tapes Specific Requirements

7.2.2.5.1 Conductive Tape Surface Resistivity

Conductive tapes used to closeout gaps or apertures **shall** be designed to meet the conductive surface resistivity requirements.

7.2.2.5.2 Conductive Tape, Grounding

The external surface of conductive tapes **shall** be connected to the spacecraft interface through the use of folded under tabs, or conductive adhesives.

7.2.2.6 Exposed Harness Specific Requirements

Harnesses that are exposed to sunlight or the ambient plasma **shall** be bundle shielded from source to destination.
N/A
N/A

7.2.3 External Surface Ground Wires

All ground wires used to ground external surfaces shall be constructed of AWG #24 or larger.

7.3 MAGNETIC CLEANLINESS

To avoid corrupting the magnetic measurements that are a prime objective of the mission, the observatory and its subsystems are required to be “magnetically clean.” The following paragraphs provide requirements and guidelines for minimizing the magnetic field generated by the observatory.

7.3.1 Minimizing Permanent Fields

Permanent fields arise from permanent magnets or magnetically soft materials that are magnetized in response to varying electrical or magnetic fields in ambient environment. Permanent fields should be minimized by: (a) strictly controlling the use of magnetic materials and (b) compensating the permanent fields.

The material described in Table 7-2 **shall** be prohibited from Observatory. Exceptions to this requirement can be made case by case upon completion of the magnetic assessment and the MMS project office approval Solar cell interconnects are made of silver-plated Kovar or Invar. Here is the suggested requirement for MMS:

Except for Kovar or Invar interconnects, the contractor shall use no magnetic parts or subassemblies. The contractor shall use no more than 20 grams of either Kovar or Invar on any solar array panel.

Table 7-2: Prohibited Magnetic Materials List

Alloy 426	Mumetal
Alloy 720[1]	Nichrome
Carbon Steel 1008	Nickel 200, 270
Chromium	Nickel Iron
Cobalt	Pelcoloy
Copperweld	Permalloy
Dumet	Platinum
Electroless Nickel (except high-phosphorous)	Remendur
Electroloy	Rodar
Elinvar	Stainless Steel 202[2]
Fenicoloy	Stainless Steel 302[2]
Ferrites	Stainless Steel 303[2]
Gridaloy M, P	Stainless Steel 304[2]
Haynes Alloy #6	Stainless Steel 403 & 405
Invar	Stainless Steel 410 & 416
Iron	Stainless Steel 430 & 446
Kovar	Stainless Steel AISI 440C
Mesoloy	Supermalloy
Molypermalllow	Ti 430
Monel K[1]	Vicalloy
Monel R	

[1]Based on a GSFC Materials Engineering Branch Technical Information Paper No. 128 entitled, "Minimizing Stray Magnetic Fields through Materials Selection".

[2]Non-magnetic (technically paramagnetic) in the annealed condition. If any of these alloys are cold worked then they will become magnetic. The alloy condition will be clearly indicated on the Material Certification that will accompany the purchase.

[3]Inconel alloys, 600, 625 and 718, are considered non-magnetic, but become magnetic at cryogenic temperatures.

7.3.2 Minimizing Stray Fields

Stray fields are due to uncompensated current loops or stray currents that result in permanent or variable magnetic moments.

The stray magnetic field associated with the total beginning of life solar panel short-circuit current output shall not exceed 6.2 nanotesla at a point 1 meter from any point on the panel.

The dipole moment of each solar array panel shall not exceed 0.031 A-m^2.

7.3.2.1 Minimizing Current Loops

Magnetic dipole moments are associated with the current loops and, if uncompensated, these can add up to large fields. The following guidelines may be used to minimize current loops:

(1) Each positive wire that carries appreciable current (> 1 mA) should be twisted with its return (see Section 8.2.2.3.6 for twisting details).
(2) Where twisting is not possible (at connector pins, for example), positive and negative power lines should be routed to minimize the enclosed area between them. In connectors this is done by placing the positive and negative pins adjacent to each other..
(3) On terminal boards, positive and negative power leads or traces should be routed to minimize the enclosed area between them.

7.3.2.2 Compensating Current Loops

It is not possible to completely eliminate current loops, and there are instances where the loop area cannot be minimized beyond a certain point. In these cases, the total field may be minimized by locating and orienting these loops in such a way as to generate opposing dipole moments that cancel each other.

7.3.2.3 Minimizing Stray Currents

Stray fields can result from uncompensated conductors or currents flowing via “sneak paths” in the structure. The contractor shall use the following techniques to minimize stray currents:

(1) Every wire carrying appreciable current (> 1 mA) should have a return associated with it.
(2) Stray currents associated with primary power can be eliminated by: (a) strict adherence to the single point grounding scheme for primary power, and (b) by isolating primary power from local signal and chassis grounds within components.
(3) Interconnections between components should be carefully analyzed to determine all current paths.
(4) On the solar cell strings, the contractor **shall** minimize the stray magnetic field of the solar array panels by alternating the current direction of solar cell strings on the front of each panel.

To meet the stray magnetic field requirement of Section 7.3.2 the Contractor **shall** also retrace the current path of each solar cell string underneath the string using expanded silver mesh or another contractor-proposed, GSFC-approved nonmagnetic conductor. The contractor **shall** electrically connect the magnetic field cancellation conductor to the negative terminal of the solar cell string, run the conductor underneath the string from the negative to the positive terminal, and terminate the conductor adjacent to the positive string termination. The width of the magnetic field cancellation conductor **shall** be approximately the same as the dimension of the solar cells in the parallel direction, allowing for sufficient space between adjacent strings to prevent shorts. This magnetic field cancellation method is conceptually illustrated in Figure 7-1.

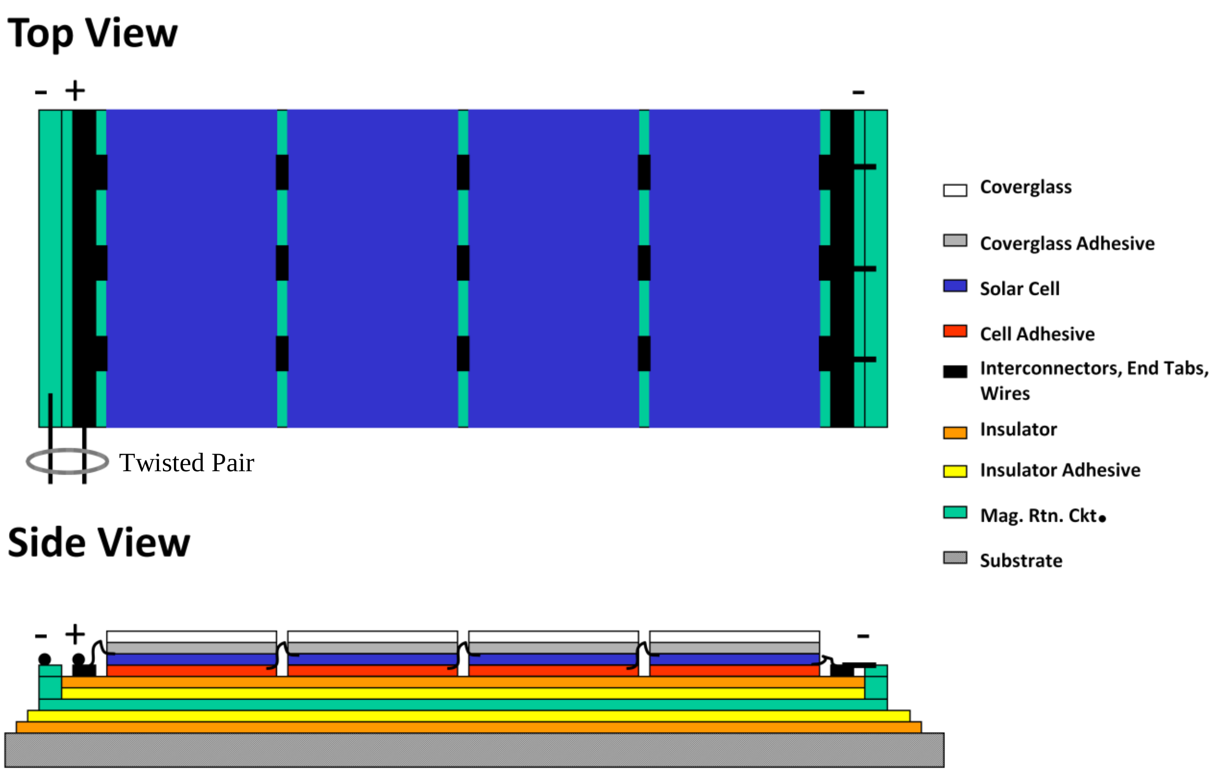


Figure 7-1 Magnetic Field Cancellation Concept

8.0 DESIGN & CONSTRUCTION REQUIREMENTS

8.1 PARTS, MATERIALS & PROCESSES (PMP)

8.1.1 EEE Parts

The *Solar Array Panels* contractor's Quality Assurance system for EEE parts **shall** be in accordance with the requirements in the SOW, 461-EPS-SOW-0010.

8.1.2 Materials

The *Solar Array Panels* contractor's Quality Assurance system for materials **shall** be in accordance with the requirements in the SOW.

All parts should be passivated and mounting surfaces on *Solar Array Panels* **shall** be conductive as defined in Section 4.4.

Aluminum parts **shall** be finished with iridite per MIL-DTL-5541, Class 3.

Titanium surfaces **shall** be finished per AMS 2488.

N/A

8.2 ELECTRICAL

8.2.1 Test Sensors

With the exception of thermocouples used in thermal ambient and thermal vacuum cycling, and in high temperature electrical measurements, test sensors **shall** be designed for flight. Unless specified to be removed before flight, test sensors will not be removed prior to flight.

N/A

8.2.2 Harness and Panel Wiring Requirements

The locations of the shunt heater, thermal and test connector, and power connector pigtail attachment points are presented in Figure 8-1.

A conceptual back side layout of the solar array panel is presented in Figure 8-2.

The contractor shall protect wire wherever abrasion may be a problem.

The contractor shall use stress relief between wire tie points to avoid strains, particularly on the solar cell string terminations.

The contractor shall address how it will stake wire.

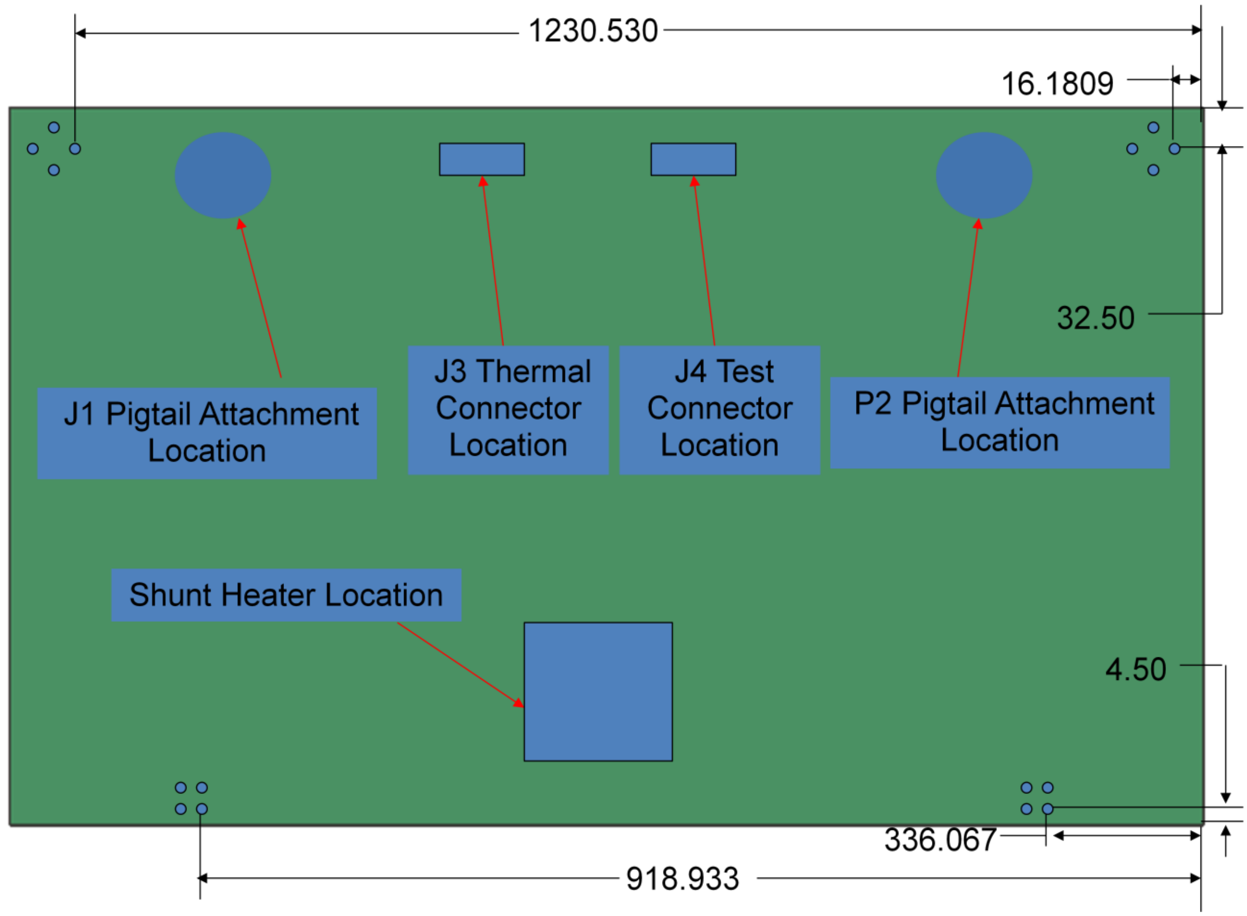


Figure 8-2. Component Locations on Back of Panel.(TBD-need locations from mechanical)

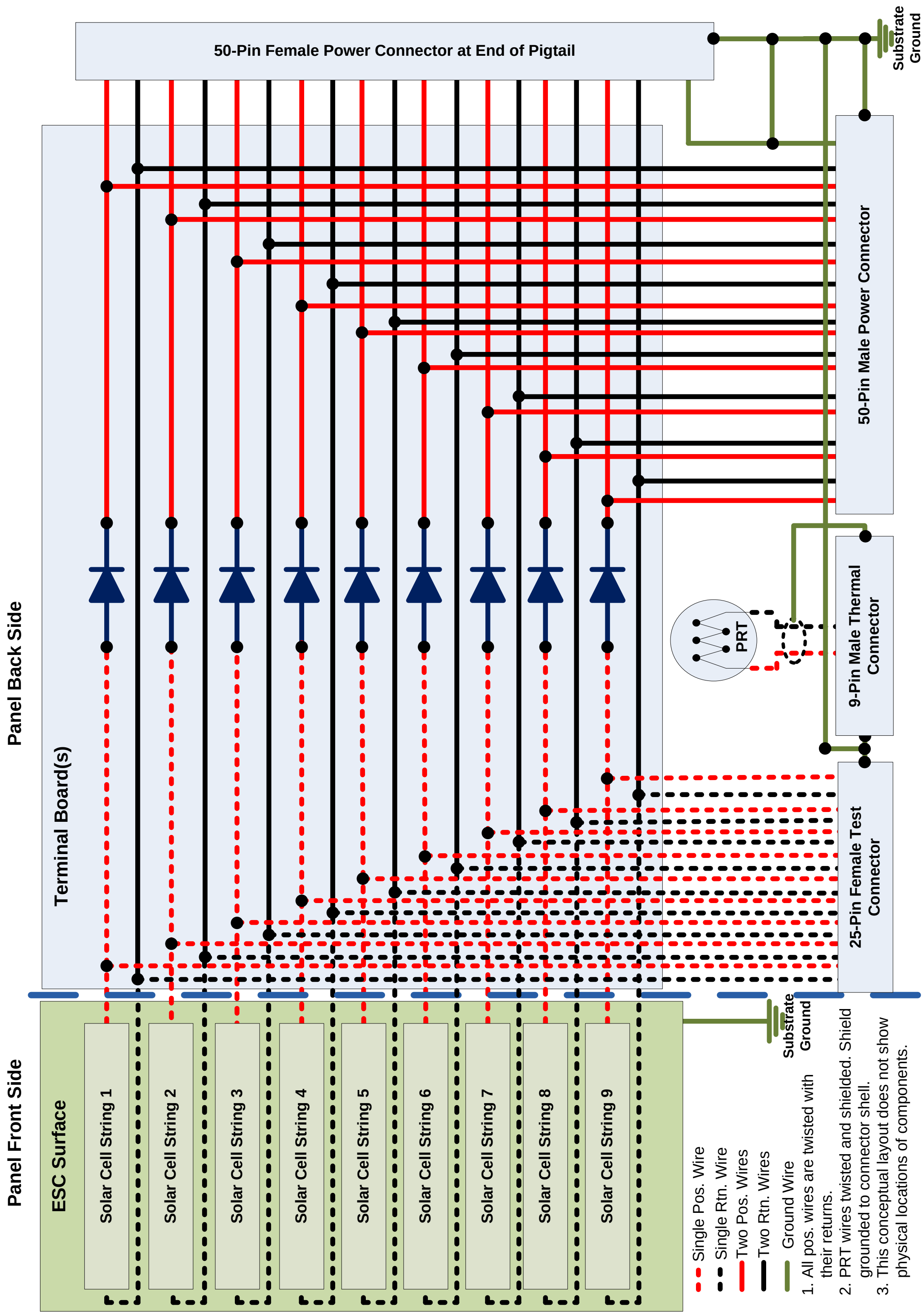


Figure 8-2. Conceptual Solar Array Panel Layout.

8.2.2.1 Connectors

N/A

8.2.2.2 Grouping of Twisted Wires

When multiple twisted wires are grouped into harness cable assemblies, the following guidelines should be followed:

The twisting should begin as close to the termination as practical without causing undue stress on the connector.

Winding should be such as to prevent the introduction of residual twist into individual conductors at the connector pin.

8.2.2.3 Wire Shielding

8.2.2.3.1 Harness Shield Termination to Connector Shell

The contractor shall terminate all wire shields to to the metallic connector shell.

8.2.2.3.2 Shielded Wire Exposure Length

Shielded wires, by necessity, will be unshielded near the immediate vicinity of their connection to the connector pins. This exposed length should be less than 2 cm in order not to compromise shielding integrity of the signal.

8.2.2.3.3 Wire Specifications

Wires that carry power generated by the solar cell strings and substrate ground wires shall meet the requirements of SAE-AS-22759/33. Shielded wires from the PRT to the connector shall meet the requirements of NEMA-WC27500

N/A

8.2.2.3.4 Return Wire

All solar array positive wires **shall** have an associated negative return wire.

8.2.2.3.5 Wire Twisting of Associated Return

The plus wire **shall** be twisted with its negative return wire.

8.2.2.3.6 Twists

The minimum number of wire twists **shall** be as shown in . Twisting should be as symmetrical as possible.

Table 8-1 Minimum Number of Wire Twists

AWG#	Twists Per Meter		
	Two Conductor	Three Conductor	Four Conductor
20	54	40	28
22 and smaller	60	54	34

8.2.2.3.1 Wire Sizes

8.2.2.3.1.1 Sizing

The contractor shall use the smallest gauge nonredundant wire (not smaller than AWG #26) that meets the derating requirement of Section 8.2.2.1.7 between the solar cell string terminations and terminal board(s). The contractor shall use redundant AWG #20 wires between the terminal boards and connectors as well as between the substrate ground and the connectors.

8.2.2.3.1.2 Minimum Wire Size

No wire smaller than AWG #26 **shall** be used.

8.2.2.3.2 Wire Derating

The current carrying capacity of the wires **shall** be derated for continuous operation at the required current levels in a vacuum, as defined in Section W1 of EEE-INST-002.

8.2.2.3.3 Redundant Wire Derating

If redundant wires are used, each wire **shall** meet the required derating criteria.

8.2.2.3.4 Wire Composition

Wire conductors should be copper or a copper alloy. High strength copper alloys may be used for wire sizes AWG #24 or smaller. The wires may be tinned or plated with suitable materials except nickel or other magnetic materials.

8.2.2.4 Connectors

8.2.2.4.1 Connector Types

Selected connector types **shall** meet the Connector and Contact Requirements defined in Section C2 of EEE-INST-002. The connector types shall be in accordance with Figure 8-5 and Table 8-4..
N/A

8.2.2.4.2 Connector Contacts

Gold plated non-magnetic contacts **shall** be used for the subminiature-D connectors.

8.2.2.4.3 Contact Derating

The current carrying capacity of the contacts **shall** be derated for continuous operation at the required current levels in a vacuum, as defined in Section C2 of EEE-INST-002.

8.2.2.4.4 Redundant Contact Derating

When redundant contacts are used for a single power source, each contact **shall** meet the required derating criteria.

8.2.2.4.5 Connector Materials

Base materials and finishes for the connector shells **shall** comply with the magnetics requirements in Section 7.3 of this specification.

8.2.2.4.6 Test Harness and Breakout Box

The contractor shall supply test harnesses and break out boxes as required by this contract's SOW.

8.2.2.4.7 Connector Savers

The contractor shall supply and use connector savers as required by this contract's SOW.

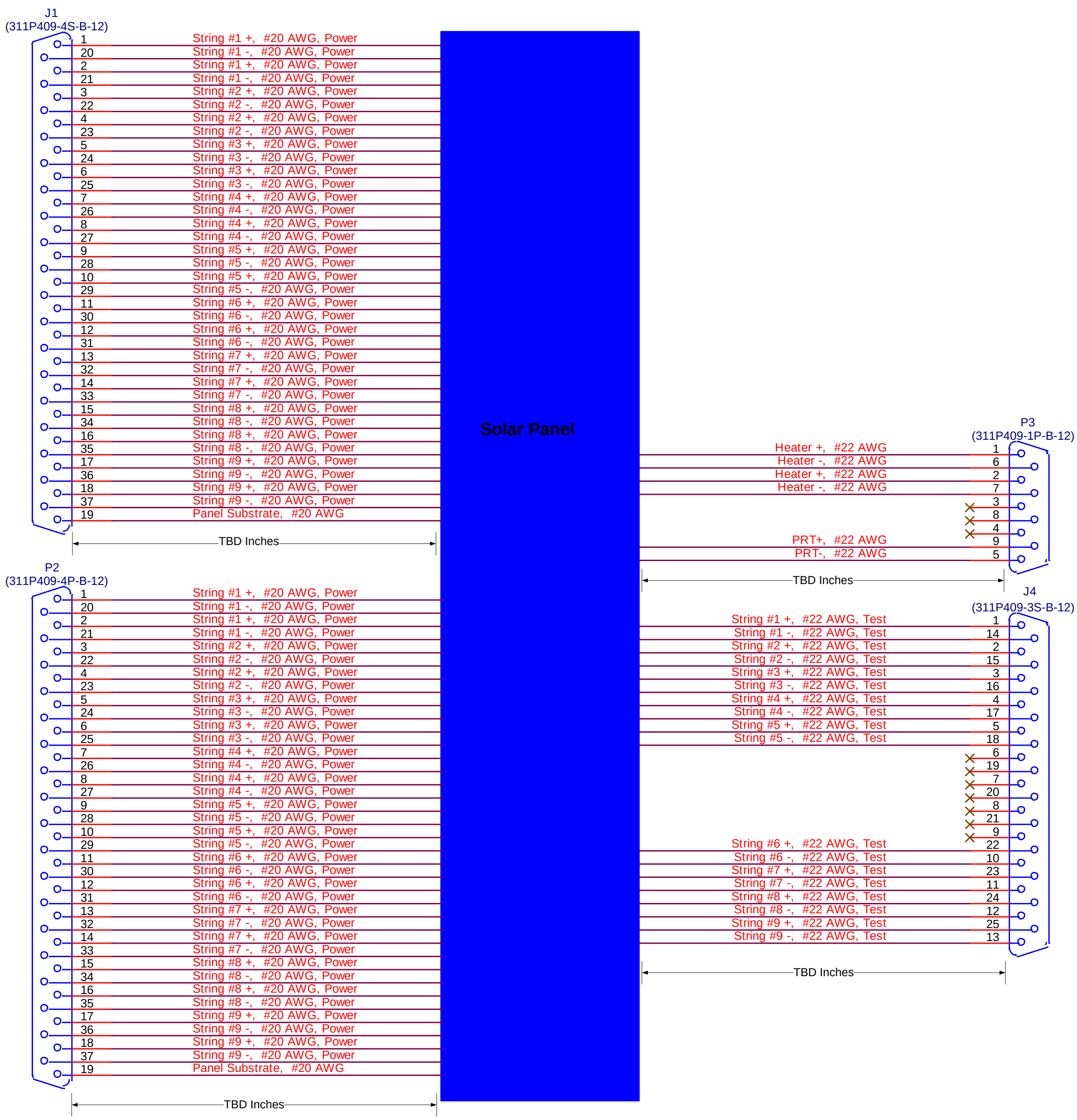


Figure 8-5. Connector Types and Pin Assignments(To be updated to remove shunt connections).

Table 8-4 Connector Descriptions.

Connector	Part Number	Function
J1	311P-409-4S-B-12	Array Power
P2	311P-409-4P-B-12	Array Power
P3	311P-409-1P-B-12	PRT
J4	311P-409-3S-B-12	Test (Solar Cell Strings, Bypass Diodes)

All connectors are rectangular, D-subminiature, nonmagnetic with crimp contacts.

8.2.2.5 Signal Segregation

Wherever possible, different classes of signals (power, digital, analog, etc.) should be separated by using separate connectors and separate harness bundles. If separate connectors are not feasible, classes of signals within a common connector should be isolated from one another. Connector pin assignments should be such that sensitive circuits are separated from potential interference sources.
N/A

8.2.2.6 Harness Support

All harnesses should be adequately supported at terminations (preferably within six inches of connectors) and at intermediate points (preferably with a spacing of 12 inches or less) to prevent damage due to handling during integration and test or due to the launch environments. Harness terminations at connectors should be supported with backshell clamps (preferred) or with backshell potting. Cable support at intermediate points should be via cable clamps that are attached to structural frames or other suitable support structures. Additional insulation in the form of harness troughs, overall jackets, rubbing strips, or grommets should be provided to prevent chafing on rivets, screws, panel edges, etc.

8.2.2.7 Harness Fabrication

Harness assemblies **shall** be fabricated per the requirements of NASA-STD-8739.3 (Soldered Electrical Connections) and NASA-STD-8739.4 (Crimping, Interconnecting Cables, Harnesses, and Wiring).

8.2.2.8 Test Harness

Test harnesses that will not be removed prior to flight **shall** be designed for flight.

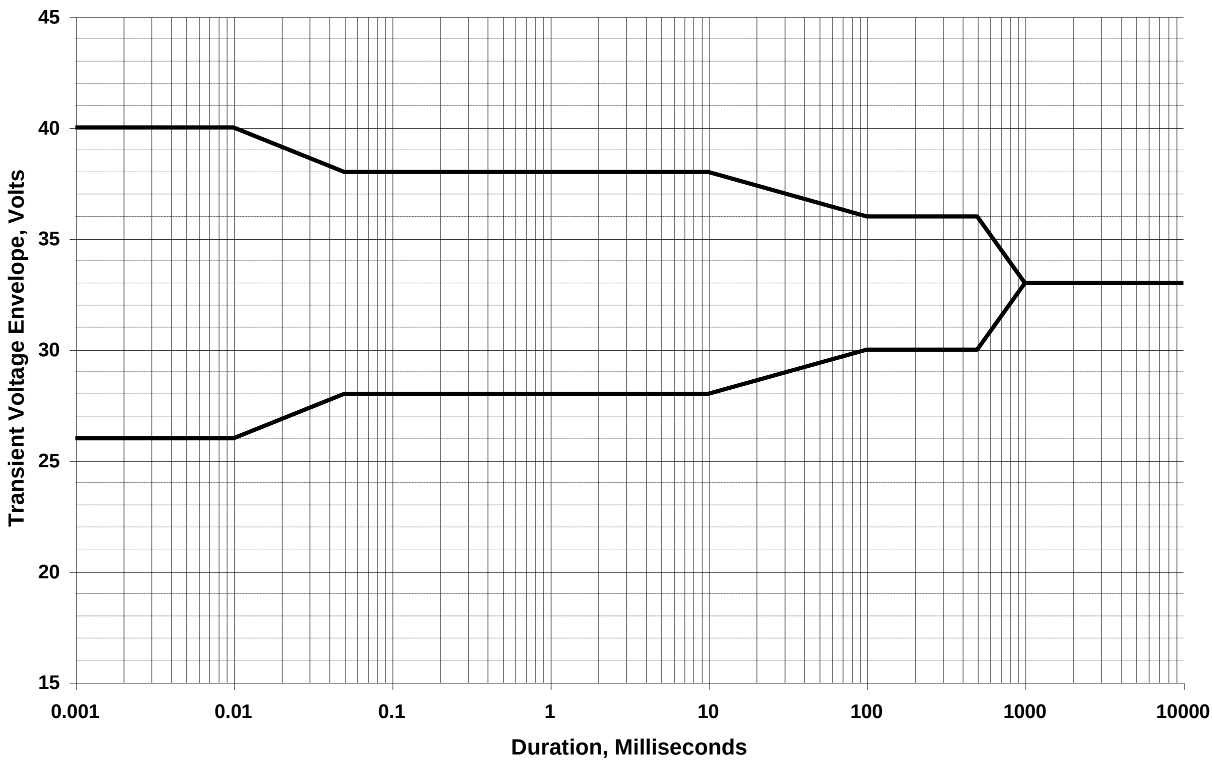
8.2.2.9 Test and Flight Signal Isolation

Test signals and flight signals should not be located in the same connector.
N/A
N/A
N/A
N/A
N/A

N/A
N/A

N/A
N/A
N/A
N/A
N/A
N/A
N/A

N/A



N/A

N/A
N/A
N/A
N/A

N/A

N/A

N/A

N/A

N/A
N/A
N/A

8.3 IDENTIFICATION AND MARKING

Each unit **shall** be permanently marked with the part number and a unique sequential serial number in the area designated on the interface control drawing in a manner to be approved by the GSFC COTR.

All markings **shall** use alcohol proof ink.
In SOW.
N/A
N/A

8.4 INTERCHANGEABILITY

Each solar array panel **shall** be directly interchangeable in form, fit, and function with other items of the same part number.

8.5 RELIABILITY

8.5.1 Mission Life

The *Solar Array Panels* **shall** meet all performance specifications throughout 1 year of ground testing and 28 months of operation in space.

8.5.2 Shelf Life

The *Solar Array Panels* **shall** not suffer any degradation in performance when stored for five (5) years either on the S/C or in bonded storage.

8.6 GROUND HANDLING

8.6.1 Lift Point Capability

The *Solar Array Panels* **shall** include lift points capable of lifting *TBD* kg.

8.6.2 Lift Point Locations

There **shall** be a minimum of three lift points, with the exact location and number agreed upon with GSFC and documented in the ICD.

9.0 LOGISTICS

N/A
N/A

9.1 TRANSPORTATION EQUIPMENT

List any requirements here that you want to levy on any transportation equipment that the contractor is supplying. Look in 540-PG-8700.2.1- for specific requirements on the Design of Dollies, Stands, and Spacecraft Shipping Containers.

10.0 VERIFICATION REQUIREMENTS

The contractor **shall** conduct a verification program that demonstrates the hardware design is qualified and meets all requirements contained in this document. Per the SOW (461-EPS-SOW-0010), the contractor will provide a verification matrix defining the method of verification for each specific requirement of this document.

10.1 VERIFICATION METHODS

Verification methods include inspection, analysis, as well as environmental, functional, and performance testing, or a combination of these techniques.

10.1.1 Inspection

Verification by inspection includes (but is not limited to) visual inspection, simple physical manipulation, gauging, measurement, and documentation examination.

10.1.2 Analysis

Verification by analysis will be used to show design margins. Also, when the particular tests required for verification are impractical, risky, unacceptably long, or prohibitively expensive, analysis may be used instead of testing, as noted in the verification matrices.

Analysis, including simulations where applicable, will also be used to guarantee that the *Solar Array Panels* and its components will perform as expected under worst-case conditions.

10.1.3 Test

Verification by test includes, but is not limited to, the evaluation of performance by use of special equipment or instrumentation, simulation techniques, and the application of established principles and procedures to determine compliance with requirements.

10.2 INSPECTION REQUIREMENTS

Verification by inspection **shall** be by one of these three methods: 1) visual inspection of the physical hardware; 2) a physical measurement of a property of the hardware, or; 3) a documentation search demonstrating hardware of an identical design has demonstrated fulfillment of a requirement.

10.2.1 Visual Inspection

Visual inspection of the physical hardware **shall** be performed by a customer appointed qualified inspector certifying that the hardware has the properties/configuration specified in the requirement.

10.2.2 Physical Measurement

Physical measurement of hardware property (i.e. mass, dimensions, etc.) **shall** be performed by a customer appointed qualified inspector demonstrating the hardware meets specific requirement.

10.2.3 Documentation Search

Verification of requirements based on similarity **shall** include supporting rationale and documentation and **shall** be approved by the GSFC COTR

10.2.4 Certification

Certification of requirements shall include supporting rationale and documentation and shall be approved by the GSFC COTR.

10.2.5 Units Verification

The contractor shall inspect documents for the use of metric units.

10.3 ANALYSIS REQUIREMENTS

Verification of performance or function through detailed analysis, using all applicable tools and techniques, is acceptable with GSFC COTR approval. Detailed descriptions of the minimum required analyses, as well as analysis requirements, are provided in the SOW.

10.4 TEST REQUIREMENTS

This section provides general test requirements on how testing is to be performed in the process of verifying that the deliverable item meets its requirements. Performance parameter measurements **shall** be taken to establish a baseline that can be used to assure that there are no data trends established in successive tests that indicate a degradation of performance trend within specification limits that could result in unacceptable performance in flight. Any requirement that exceeds previous qualification test data **shall** be presented to the MMS project as part of the verification planning process described in the SOW, for evaluation and a possible delta qualification test.

10.4.1 Definitions

The hardware definitions are reproduced here from Section 1.8 of GEVS (GSFC-STD-7000).

Qualification or Prototype Hardware: ”Hardware of a new design; it is subject to a design qualification test program; it is not intended for flight.” The purpose of the tests on this hardware is to prove that a new design meets one or more of its design requirements. Qualification testing is performed at maximum expected flight levels plus a margin. Test durations are typically longer than for acceptance tests.

Protoflight Hardware: ”Flight hardware of a new design; it is subject to a qualification test program that combines elements of prototype and flight acceptance verification; that is, the application of design qualification test levels and flight acceptance test durations.” The purpose of the test on this hardware is to prove that a new design meets one or more of its design requirements. Protoflight testing is performed at maximum expected flight levels plus a margin. Test durations are typically the same as for acceptance tests.

Follow-On (Acceptance) Hardware: Flight hardware built in accordance with a design that has been qualified either as prototype or as protoflight hardware; follow-on hardware is subject to a flight acceptance test program.” The purpose of the test on this hardware is to prove that a particular flight unit has been manufactured properly. The design has already been proven during a qualification or protoflight test program. Acceptance testing is performed at maximum expected flight levels.

10.4.2 Test Factors

The following test factors and durations, shown in Table 10-1, **shall** be used for prototype, protoflight, and follow-on flight hardware.

Table 10-1 Test Factors and Durations

Test	Qualification/Prototype		Acceptance
Acoustic Level Duration	 Limit Level +3dB 2 Minutes		 Limit Level 1 Minute

10.4.3 Test Tolerances

Tolerances for the various mechanical test parameters are given in Table 10-2.

Table 10-2 Test Tolerances

Test	Test Parameter	Tolerance

Test	Test Parameter	Tolerance
Acoustics	Overall Level: 1/3 Octave Band Frequency: $f \leq 40$ Hz $40 < f < 3150$ Hz $f \geq 3150$ Hz	≤ 1dB + 3, - 6 dB ± 3 dB + 3, - 6 dB
Temperature		± 2 °C
Humidity		± 5% RH
Loads	Steady-State (Acceleration): Static:	± 5% ± 5%
Mass Properties	Weight: Center of Gravity: Moments of Inertia Products of Inertia	± 0.2% ± 2 mm ± 1 % ± 5 %
Mechanical Shock	Response Spectrum: Time History:	+ 25%, - 10% ± 10%
Pressure	>1.3 x 10^4 Pa (> 100 mm Hg): 1.3 x 10^4 to 1.3 x 10^2 Pa (100 mm Hg to 1 mm Hg): 1.3 x 10^2 to 1.3 x 10^1 Pa (1 mm Hg to 1 micron): < 1.3 x 10^1 Pa (< 1 micron):	± 5% ± 10% ± 25% ± 80%
Vibration	Sinusoidal: Amplitude Frequency Random: RMS Level Accel. Spectral Density	± 10% ± 2% ± 10% ± 3 dB

10.4.4 Test Restrictions

10.4.4.1 Failure During Tests

When a failure (non-conformance or trend indicating that an out-of-spec condition will result) occurs, determination will be made as to the feasibility and value of continuing the test to its specified conclusion. The test **shall** be stopped if equipment fails during testing in cases where this failure will result in damage to the equipment. Otherwise, the test **shall** be completed to obtain as much information as possible. If corrective action is taken, the test will be repeated to the extent necessary to demonstrate that the test item’s performance is satisfactory. If corrective action taken as a result of failure affects the validity of previously completed tests (e.g., redesign of a component), prior tests will be repeated.

If during a test sequence, a test item is operated in excess of design life and wears out or becomes unsuitable for further testing from causes other than deficiencies, a spare will be substituted, and previously completed tests will be repeated to the extent necessary.

No replacement, adjustment, maintenance, or repairs are authorized during testing. This requirement does not prevent the replacement or adjustment of equipment that has exceeded its design operating life during tests, provided that after such replacement, the equipment is tested as necessary to assure its proper operation. A complete record of any exceptions taken to this requirement **shall** be included in the test report.

10.4.4.2 Modification of Hardware

Once the formal acceptance test has started, cleaning, adjustment, or modification of test hardware **shall** not be permitted.

10.4.4.3 External Adjustment

The *Solar Array Panels* **shall** be designed so that no external adjustments are required after start of acceptance or qualification testing.

10.4.4.4 Re-Test Requirements

If any event, including test failure, requires that a *Solar Array Panels* be disassembled and reassembled, then all tests performed prior to the event must be considered for repeat. If the unit has multiple copies of the same build, then all units must be examined to determine if the problem is common. If all copies require disassembly for repair, then each must receive the same test sequence.

10.5 REQUIRED TESTS

Summary of Tests on Solar Cells and CICs:

- Solar Cell and Bypass Diode Qualification per AIAA-S-111.

Summary of Tests on Qualification Coupons:

- Solar Panel Life Cycle Coupon Test with Humidity Exposure per AIAA-S-112 as tailored in this specification
- ESD Coupon Test per AIAA-S-112
- VCM Test
- UV Radiation Effects Characterization
- ESD Test
- Bypass Diode Characterization
- Solar Absorptance Characterization
- Angle of Incidence Characterization
- CIC Electrostatic Discharge Sensitivity Characterization
- Emittance Characterization

Summary of Tests on Full-Size Prototype Panel:

- Acoustic Exposure
- Thermal Vacuum Bakeout

- Thermal Vacuum Cycling
- Bend Test

Summary of Tests on Flight Panels:

- Acoustic Exposure
- Thermal Vacuum Bakeout
- Thermal Vacuum Cycling

10.5.1 Solar Cell and Bypass Diode Qualification Tests

The MMS solar cell must be qualified to AIAA S-111-2005, *Qualification and Quality Requirements for Space Solar Cells.* The qualification must be completed prior to the start of cell lay down on the flight panels.

The contractor may take or may have taken the following exceptions to S-111:

•The contractor need not meet the requirements of S-111, Section 7.2.3.3.2, LEO Coupon.

•The contractor may use a Class B Solar Simulator or best effort simulator to meet the illumination requirements of S-111, Section 7.2.3.3.1, GEO Coupon.

•The contractor may meet the requirements of S-111, Section 7.2.3.3.1 by testing to the requirements of Section 7.1 of AIAA S-112-2005, *Qualification and Quality Requirements for Space Solar Panels* as required in section 10.5.2.

10.5.2 Solar Panel Qualification Tests

The Contractor shall qualify the MMS solar array panels using AIAA S-112-2005, “Qualification and Quality Requirements for Space Solar Panels” as tailored by this Specification.

The contractor shall use the same coupon for all of the following tests. Section numbers below refer to S-112 unless otherwise indicated.

Solar Panel Life Cycles Coupon Test with Humidity Exposure, Section 7.1

Acoustic Test, Section 7.2

VCM Test, Section 7.2

UV Radiation Effects Characterization, Section 8.1

ESD Test, Section 7.3

Bypass Diode Characterization, Section 8.5

Solar Absorptance Characterization, Section 8.4

The contractor may perform the following tests required by S-112 on a different coupon or the same coupon specified above.

Angle of Incidence Characterization, Section 8.2

CIC Electrostatic Discharge Sensitivity Characterization, 8.7

The following tests are waived

Atomic Oxygen Characterization, Section 8.2

The following tests or requirements are modified

Sample: Life-Cycle Coupon/Subcoupons, Section 7.1.2 add the requirement that three cells be broken and repaired prior to the start of environmental exposure. The contractor shall break one cell at a positive string termination, another cell at a negative string termination ,and another in the center of a row.

Electrical Test, Section 7.1.3.1.2 change 80C to TBDC (5 places).

The Humidity Test, Section 7.1.3.4 shall be shortened to 45 days.

The solar simulator output required during an environmental exposure shall be a best effort rather than the simulator specified in S-112 Section 6.2.

The Acoustic panel described in Section 7.2.2 shall be the fully-populated Prototype panel.

Normal emittance may be measured in Section 8.3.

10.5.3 Solar Array Panel Life Cycle Coupon Tests

Section 7.1 of S-112 requires a life cycle coupon or coupons. Section 5.1 of this document requires the same coupon in the life cycle test be used for additional S-112 tests. It may therefore be necessary to use more than one coupon in the S-112 Section 7.1 tests so that one of them may be used for the subsequent tests which may require a smaller coupon. The coupon(s) used in the cycling test must include at least two samples of all of the parts to be used on the MMS solar panels.

In S-112, the bakeout temperature shall be increased to TBDC. The bakeout duration shall be increased to 96 hours.

The temperature extremes for the life cycle coupon test shall be 10°C beyond the extremes and for 1.5X the number of cycles in Section 6.6 of this specification.

10.5.4 Full-Size Prototype Solar Panel Tests

Acoustic Exposure, Section 7.2
Bend Test, Section 8.3
Thermal Vacuum Bakeout per Section 10.5.12 of this specification.
Thermal Vacuum per Section 10.5.13 of this specification.

10.5.4.1 Test Condition Power Verification

The Contractor shall use a solar simulator calibrated with a set of balloon-flown primary or secondary standard solar cells to determine the current-voltage (I-V) characteristics of each panel through the panel terminals at 23º ± 5ºC.

The Contractor shall extrapolate the measured data to obtain the I-V curve for a panel operating at 28ºC and AM0.

Type: Measurement.

Level: Panel.

Schedule: Per Appendix B and Appendix C.

Pass/Fail Criteria: The verification shall fail if the power at the specified load voltage of a panel does not meet the requirements of Section 4.1.2.

10.5.4.2 Power at Highest Predicted Operating Temperature Verification

The Contractor shall use a solar simulator calibrated with a balloon-flown primary or a secondary standard solar cell to determine the current-voltage (I-V) characteristics of each panel through the panel terminals with the panel operating at 60º +10/-0ºC at AM0.

The Contractor shall extrapolate the measured data to obtain the I-V curves for a panel temperature of 60ºC and AM0.
Type: Measurement.

Level: Panel

Schedule: Per Appendix B and Appendix C.

Pass/Fail Criteria: The verification shall fail if the measured Isc, Imp, Voc, or Vmp of the flight or qualification panels are less than the values extrapolated per Section 4.1.3 by more than 3%. The verification shall also fail if, in the judgment of the Contractor, the shape of the current-voltage curve indicates a problem that could include, but is not limited to: solar cell cracks, wiring discontinuities, diode malfunctions.

10.5.4.3 End of Life Power Verification

The Contractor shall predict current-voltage curves for the flight solar panels for the conditions specified in Section 4.1.4.

Type: Analysis.

Level: Panel.

Schedule: At Design Conformation Review (DCR).

Pass/Fail Criteria: At 40ºC, after TBD months, the power of each panel, taken at the solar cell string terminations, shall exceed TBDW at a load voltage of 35V with the panel normal 5º off the sun line.

10.5.4.4 Bypass Diode Functionality Verification

The Contractor shall pass a minimum of 120% of the Isc of each string on each panel through the bypass diode circuits. This test shall be conducted at 23º ± 5ºC with the results extrapolated to 28ºC.

Type: Test.

Level: Panel.

Schedule: Per Appendix B and Appendix C.

Pass/Fail Criteria: The voltage dropped by the bypass diodes shall not vary more than ±3% from the first panel level measurement to the last at an extrapolated temperature of 28ºC.

10.5.4.5 Bypass Diode Functionality at High Temperature Verification

The Contractor shall pass a minimum of 120% of the Isc of each string on each panel through the bypass diode circuits with the panels at 60º +10º/-0ºC.

Type: Test.

Level: Panel.

Schedule: Per Appendix B and Appendix C.

Pass/Fail Criteria: The voltage dropped by the bypass diodes shall not suggest any anomalies in the bypass diode circuit.

10.5.4.6 Substrate insulation Resistance Verification

The Contractor shall make connection to the cell circuits through each panel's terminals and shall tie all positive and negative power leads together. The Contractor shall then measure the resistance between these tied together leads and the panel's substrate. The Contractor shall make this measurement at 500 volts direct current (Vdc) with the current limited to 20 microamperes or less with the positive test voltage on the cell circuits

Type: Measurement. The insulation resistance values shall be recorded.

Level: Panel.

Schedule: Per Appendix B and Appendix C.

Pass/Fail Criteria: The panel shall fail verification if its substrate insulation resistance is less than that required by Section 4.1.7.

10.5.4.7 Solar Cell Mechanical Verification

The contractor shall visually inspect each solar cell on the qualification and flight panels for compliance with section 4.1.10.1.

The contractor shall inspect with the unaided eye and under a minimum of sevenpower magnification.

The contractor shall perform optional inspections, which it determines are advisable, at its discretion.
Type: Inspection.

Level: Panel.

Schedule: Per Table TBD

Pass/Fail Criteria: Each solar cell shall meet the requirements of section 4.1.10.1 or the contractor shall remove the cell from the panel and replace it.

If more than 4% of the cells on the cell qualification panel shall crack as a result of test, the panel shall fail qualification.

10.5.4.8 Cover Orientation Verification

The contractor shall visually inspect each solar cell cover for compliance with section 3.6.1.
Type: Inspection.
Level: Panel.
Schedule: Per Table TBD.

Pass/Fail Criteria: No more than 0.1% of a panel's covers shall fail this test.

10.5.4.9 Flight Connector Type Verification

The contractor shall propose the type, level, schedule and pass/fail criteria for verifying the connector type, connector mounting adequacy, and wiring.

10.5.4.10 Platinum Resistance Thermometer Type Verification

The contractor shall propose the type level, schedule and pass/fail criteria for verifying the resistor type.

10.5.4.11 Platinum Resistance Thermometer Mounting Verification

The contractor shall propose the type level, schedule and pass/fail criteria for verifying the platinum resistor thermometer mounting.

10.5.4.12 Platinum Resistance Thermometer Performance Verification

Type: Measurement.

Level: Component.

Schedule: Per Table TBD

Pass/Fail Criteria: The output from each platinum resistor thermometer shall meet the requirements of 4.1.12.3 or this requirement is failed.

During the thermal vacuum test or thermal cycling test, the platinum resistor thermometer shall additionally be shown to operate without discontinuity in resistance or this requirement is failed.

10.5.4.13 Radius of Curvature Verification

The contractor shall perform a bend test to the radius of curvature specified in Section 4.1.9 about both the long and short axes on the prototype panel.

Type: Test

Level: Prototype Panel

Schedule: Per Table IV.

Pass/Fail Criteria: The prototype panel shall pass all the functional tests required by this specification after the bend test.

10.5.4.14 Parts and Subassembly Layout Verification

The contractor shall propose methods and schedules for verifying the parts and assembly layout.

10.5.4.15 Radiation Hardness Verification

The Contractor shall document the radiation hardness assessment for each EEE part with respect to TID .For the solar cells, the contractor shall document the radiation degradation characteristics of the cell in terms of 1-MeV electron equivalent fluence. Test plans and reports for parts that require radiation testing shall be submitted to the NASA/GSFC COTR for review.

Type: Analysis

Level: Panel

Schedule: With the Design Conformance Review Presentation Package

Pass/Fail Criteria: The analysis shall demonstrate that the vendor-selected parts will not fail in the MMS orbit.

10.5.4.16 Allowable Degradation Due to Depressurization Verification

Type: Certification.

Level: Panel.

Schedule: By DCR

Pass/Fail Criteria: The contractor shall certify that it meets the requirements of Section TBD

10.5.4.17 Mission Life Verification

The contractor shall certify that it has conducted a test program to demonstrate that the solar panels have the required mission life.

The contractor shall certify that it has not knowingly limited the mission life of the panels to less than the required mission life.

10.5.4.18 Shelf Life Verification

The contractor shall certify that the solar panels will have a shelf life greater than 5 years when packaged to its specifications.

10.5.4.19 Allowable Degradation Due to Humidity Verification

Type: Certification.

Level: Panel.

Schedule: By MRR

Pass/Fail Criteria: The contractor shall certify that it meets the requirements of section 4.1.19 by the tests required by AIAA S-111-2005 and AIAA S-112-2005.

10.5.4.20 Substrate Ground Verification

The contractor shall verify the substrate ground with an ohm meter.

10.5.4.21 Cleanliness Verification

Immediately prior to shipment, the contractor shall inspect the panels to the requirements of JSC-SN-C-005 to the highly sensitive level using both white and black light inspections.

Immediately prior to shipment, the contractor shall verify the cleanliness of the array by backlight inspection per IEST-STD-CC1246D.

Type: Inspection.

Level: Panel.

Schedule: Per Table TBD

Pass/Fail Criteria: The inspection shall meet the visibly clean highly sensitive requirements of JSC-SN-C-005.

If not, the contractor shall clean the "dirty" areas until the requirement is met.

The contractor shall achieve cleanliness level 450A per IEST-STD-CC1246D.

10.5.4.22 Wiping and Cleaning Materials Verification

Type: Inspection.

Level: CIC and Panel.

Schedule: On every use.

Pass/Fail Criteria: Cleaning materials shall meet the requirements of section 7.1.3 or fail this verification.

10.5.4.23 Glove and Finger Cot Verification

Type: Inspection.

Level: CIC and Panel.

Schedule: On every use.

Pass/Fail Criteria: Gloves shall meet the requirements of 7.1.4 or fail this verification.

10.5.4.24 Room Cleanliness Verification

Type: Measurement.

Level: Facility.

Schedule: Every six months.

Pass/Fail Criteria: The assembly area shall meet the requirements of 7.1.5 or fail this verification.

10.5.4.25 Assembly Room Temperature Verification

Type: Measurement.

Level: Facility.

Schedule: Every day.

Pass/Fail Criteria: The assembly area shall meet the requirements of 7.1.6 or fail this verification.

10.5.4.26 Assembly Room Humidity Verification

Type: Measurement.

Level: Facility.

Schedule: Every day.

Pass/Fail Criteria: The assembly area shall meet the requirements of 7.1.7 or fail this verification.

10.5.5 Mass Properties Measurement

Measurement of the weight and center of gravity of each flight hardware component will be made to show compliance with requirements and to provide accurate data for the observatory mass properties control program. Center of gravity at the component level will be referenced to the component to spacecraft mounting interface.

10.5.5.1 Substrates

The contractor shall measure the mass and center of gravity of each qualification, prototype, and flight substrate after fabrication and before population with solar cells or any other components.

10.5.5.2 Completed Panels

The contractor shall measure the mass and center of gravity of each completed qualification, prototype, and flight panel after all components have been added.

10.5.6 Static Loads/Strength Test

The contractor is not required to verify this requirement.

10.5.6.1 Sine Burst

The contractor is not required to verify this requirement.

10.5.6.2 Static Pull

The contractor is not required to verify this requirement.

10.5.7 Sine Sweep Survey

The contractor is not required to verify this requirement.

10.5.8 Sine Vibration

The contractor is not required to verify this requirement.

10.5.9 Random Vibration

The contractor is not required to verify this requirement.

10.5.10 Acoustic Test

The acoustic test will be conducted in an area large enough to maintain a uniform sound field at all points surrounding the solar array panel(s) under test. The sound pressure levels at various frequencies will be as specified in the Environmental Requirements section. The contractor shall perform a functional test before and after the acoustic test.

10.5.11 Shock

The contractor is not required to verify this requirement.

10.5.12 Thermal Vacuum Bake-out

The *contractor shall bake out the Solar Array Panels* prior to thermal vacuum cycling to reduce outgassing of contaminants to meet the requirements of Section 7.1.2.2.2. The rate measured at the TQCM **shall** be adjusted to account for chamber geometry, presence of cold sinks, chamber pumping speed, view factors of the TQCM, and any other factors necessary to assure an accurate measurement of the total outgassing per unit time per Kg mass of the unit under test.

The contractor shall bake the panels at a temperature of TBD+5/-0C in a vacuum of 1 x 10-5 Torr or less for at least 96 hours including verification.

The contractor shall maintain the TQCM at -20 C throughout the test to measure total volatile out gassed condensables without the influence of water vapor. The TQCM must have a representative view of the hardware.

The contractor shall collect and deliver to GSFC: chamber configuration, including chamber size, use of shrouds, TQCM location, cold finger and scavenger plate locations, if used, and general test setup; TQCM readings, taken a minimum every 0.5 hours; hardware temperature; chamber and shroud temperature; TQCM temperature; and pressure.

Prior to loading the chamber, the contractor shall allow a minimum of two hours for a GSFC representative to inspect the chamber, its equipment and its configuration.

The TQCM readings after lowering the temperature of the flight hardware to a stable TBDC +5/-0C shall meet the requirements of section 7.1.2.2.2 for 4 continuous hours or the contractor shall notify GSFC.

10.5.13 Thermal Vacuum Test

The contractor shall thermal cycle each flight panel in a vacuum of 1 x 10--5 Torr or less. The contractor shall perform both the thermal vacuum cycling in a chamber with a shroud at approximately liquid nitrogen temperatures.

The contractor shall cycle the flight panels at 10C beyond the operational temperature extremes specified in section 6.6 for 11 cycles and to the survival temperature extremes specified in section 6.6 for 1 cycle.

The contractor shall fix at least 6 calibrated temperature sensors over each flight panel and use the panels' platinum resistor thermometers to monitor temperature.

The contractor shall cycle to the temperature extremes based on the average reading of the temperature sensors.

The temperature gradients across the panels shall be limited to ±20C.

The period for one cycle shall be greater than 1.54 hour, excluding the dwell.

The dwell at the temperature extremes shall be greater than 1 hour.

The rate of temperature change between cold and hot limits shall not exceed 30C per minute.

The contractor shall send current through each panel circuit, through the shunt heaters, and through the platinum resistor thermometers using the panel connectors during these tests.

The contractor shall continuously monitor the currents with a strip chart recorder channel dedicated to that circuit, heater, or resistor.

At no time, however short, shall the strip chart recorder not monitor the current.

The contractor shall pass current through the cells during the first three cycles, to test the cells, pass current through the bypass diodes during the second three cycles, pass current through the cells during the seventh through ninth cycle, and pass current through the bypass diodes during the last three cycles.

The reverse current through the cells shall be conducted through a flight quality test connector, which the contractor shall mount to the flight panels that make connection to the anode side of each string's blocking diode and the service connector contacts that make connection to each string's return.

The Contractor shall not employ mechanical connections, other than flight quality crimps, during the thermal vacuum exposure.

During the pump-down, the contractor shall monitor power line voltages, to demonstrate the absence of corona discharge and multipaction.

Transitions from cold to hot conditions increase contamination hazards because material that has accreted on the chamber walls may evaporate and deposit on the relatively cool solar panels. Transitions will be conducted at rates sufficiently slow to prevent this from occurring. Testing shall start with a hot and end with a hot soak, in this case met by the out gassing verification, see section TBD, to minimize this risk.

Pass/Fail Criteria: Any discontinuity showing in a strip chart recording shall fail the verification.

Any defects or reduction of power output outside the limits of the requirements of this specification shall fail the verification.

Any mechanical damage to the panel, including the substrate and contractor installed components, that shall question their ability to perform adequately during launch or flight shall fail the verification.
N/A
See 10.5.3.N/A
N/A
N/A
N/A
N/A
N/A

10.5.14 Electrostatic Cleanliness Verification

Each individual component on the front surface of the *Solar Array Panels* **shall** be tested for surface conductivity and charge bleed-path to the substrate ground pins on the panel connectors.

10.5.15 Magnetic Tests

Magnetics testing will be performed by NASA/GSFC personnel upon completion of fabrication of the prototype panel as specified in the SOW, 461-EPS-SOW-0010.

Table III
Schedule of Flight Panel Level Verifications

Order of Tests is Down Column; Then Move to the Next Column
Contractor may arrange order of tests in any column for convenience

	Section Number	Prior to Purchase of Panel Parts and Prior to DCR	On Completion of Panel Substrates	After Completion of Panel Fabrication	After Acoustic Exposure	During Thermal Vacuum and Bake Out	After Thermal Vacuum and/or Bake Out	After Final Repair			
End of Life Power	10.5.4.3	A									
Magnetic Field	10.6.6	A		M							
Radius of Curvature	3.19.4	A									
Cleanliness	3.43.2		I	I	I		I	I			
Inspect for Mechanical Damage to Substrate and Other Components*	5.2.1.1		I	I	I		I	I			
Substrate Mass	3.19.1		M								
Cell Mechanical (Stereomicroscopic Inspection)	3.31.1			I	I		I	I			
Cover Orientation	3.32.1			I				I			
Indium Tin Oxide Resistance	3.32.4			M	M		M	M			
Resistance between ESC Surface and Substrate Ground				M	M		M	M			
Panel Outgassing	10.6.3					M					
Panel Performance in Thermal Vacuum (Continuity Measurements)	10.6.4					M					
Platinum Resistor Performance	3.38.6			M	M	M	M	M			
Panel Mass	10.6.1			M	M		M	M			
Insulation Resistance of Solar Panels	10.5.4.6			M	M		M	M			
Test Condition Power	10.5.4.1			M	M		M	M			
Power at Highest Predicted Temperature	10.5.4.2			M	M		M	M			
Bypass Diode Functionality	10.5.4.4			M	M		M	M			
Bypass Diode Functionality at Hi Temperature	10.5.4.5			M	M		M	M			
	"A" represents an analytical verification										
	"I" represents verification by inspection										
	"M" represents verification by measurement.										

APPENDIX A ABBREVIATIONS AND ACRONYMS

Abbreviation/ Acronym	Definition
AC	Alternating Current
AFT	Abbreviated Functional Test
Al	Aluminum
CCB	Configuration Control Board
CCR	Configuration Change Request
CE	Conducted Emissions
CG	Center of Gravity
CM	Configuration Management
CMO	Configuration Management Office
CMOS	Complementary Metal Oxide Semiconductor
COTR	Contracting Officer's Technical Representative
CPT	Comprehensive Performance Test
CS	Conducted Susceptibility
CVCM	Collected Volatile Condensable Mass
DA	Double Amplitude
DC	Direct Current
DDD	Displacement Damage Dose
DILS	Deliverable Items List and Schedule
EED	ElectroExplosive Actuators
EEE	Electrical, Electronic, and Electromechanical
ELDR	Enhanced Low Dose Rate
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EOL	End of Life
ESD	Electrostatic Discharge
FS	Factor of Safety
FT	Functional Test
GeBK	Germanium Black Kapton
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
ICD	Interface Control Drawing
I&T	Integration and Test
ITO	Indium Tin Oxide
LET	Linear Energy Transfer
LPT	Limited Performance Test
LVDS	Low Voltage Differential Signal
MBU	Multi Bit Upset
MLI	Multi-Layer Insulation

Abbreviation/ Acronym	Definition
MMS	Magnetospheric Multiscale
Mohms	Megaohms
MOP	Maximum Operating Pressure
MOSFET	Metal Oxide Semiconductor Field-Effect Transistor
MS	Margin of Safety
NASA	National Aeronautics and Space Administration
NEA	Non-Explosive Actuators
NIEL	Non-Ionizing Energy Loss
OSR	Optical Solar Reflector
PDL	Product Design Lead
QCM	Quartz Crystal Monitor
RE	Radiated Emissions
RF	Radio Frequency
RS	Radiated Susceptibility
SC	Spacecraft
SCoRe	Signature Controlled Request
SEB	Single Event Burnout
SEGR	Single Event Gate Rupture
SEE	Single Event Effects
SEFI	Single Event Functional Interrupt
SEL	Single Event Latchup
SEM	Scanning Electron Microscope
SEU	Single Event Upset
SHE	Single Hard Error
SOW	Statement of Work
SPL	Sound Pressure Level
STP	Solar Terrestrial Probe
TBD	To Be Defined
TBR	To Be Reviewed
TID	Total Ionizing Dose
TML	Total Mass Loss
UUT	Unit Under Test
VDA	Vapor Deposited Aluminum
VDC	Voltage, Direct Current